EFFECT OF THROTTLING SUCTION ON A THREE-INCH DAYTON CENTRIFUGAL PUMP

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The effect of throttling
suction on a three-inch

THE

EFFECT OF THROTTLING SUCTION

ON A

THREE-INCH DAYTON CENTRIFUGAL PUMP

A THESIS

PRESENTED BY

B. F. McAULEY J. M. SPITZGLASS

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

MECHANICAL ENGINEERING

1909

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The Effect of Throttling the Suction on a Three Inch Dayton Centrifugal Pump.

Introduction.

In starting to investigate the effect of throttling the suction on the efficiency and capacity of a three inch Dayton centrifugal pump it was at first decided to investigate two important phases of the subject.

First: Is it more efficient to cut down the capacity of the pump, when necessary, by means of throttling the suction or by throttling the discharge?

Second: Is it more efficient, other things being equal, to place the pump near the level of the inlet water and use only the discharge pressure; or to raise the pump above the inlet water and thus secure the benefit of the combined suction and discharge heads? However, the pump must be kept within the practical limit of the barometric column.

As soon as the investigation was started, a third and very important phase was introduced. It was found that when operating at full capacity the suction inlet throttled itself to such an extent that there was scarcely any range where the suction could be throttled. The question naturally arose as to the benefit of having fifteen inches of mercury in the suction pipe when the level of the sump was only two and one half feet below the center of the pump.

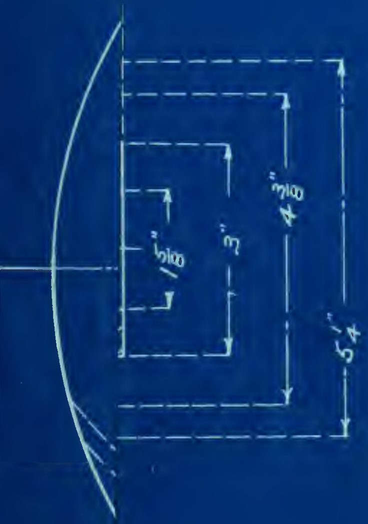
With these three phases in view several series of runs were made under a great variety of conditions. The tabulated data, results and curves are given in due order on the following pages. In order more fully to explain the action of the pump the curves of a couple of separate tests were combined on one sheet.

The Pump.

The pump was manufactured by the Dayton Hydraulic Machinery Company of Dayton Ohio, and is of the three inch single suction type. It is guaranteed to deliver two hundred gallons per minute against a total head of fifty feet when running at a speed of twelve hundred revolutions per minute. The pump was direct-connected to a ten horse power variable-speed motor, thru a flexible coupling. One half of this coupling was flanged so that it formed a ten inch by six inch pulley for driving by a belt if so desired.

The impeller is made from cast iron and is of the latest enclosed type with logarithmic spiral vanes. The impeller was machined to a smooth finish on the outside while the inside was only thoroughly cleaned. A picture of the impeller is given in plate 2 while an approximate drawing is given in plate 3.

A drawing of the casing of the pump is given in plate 4 showing the position of guide vanes and discharge opening.



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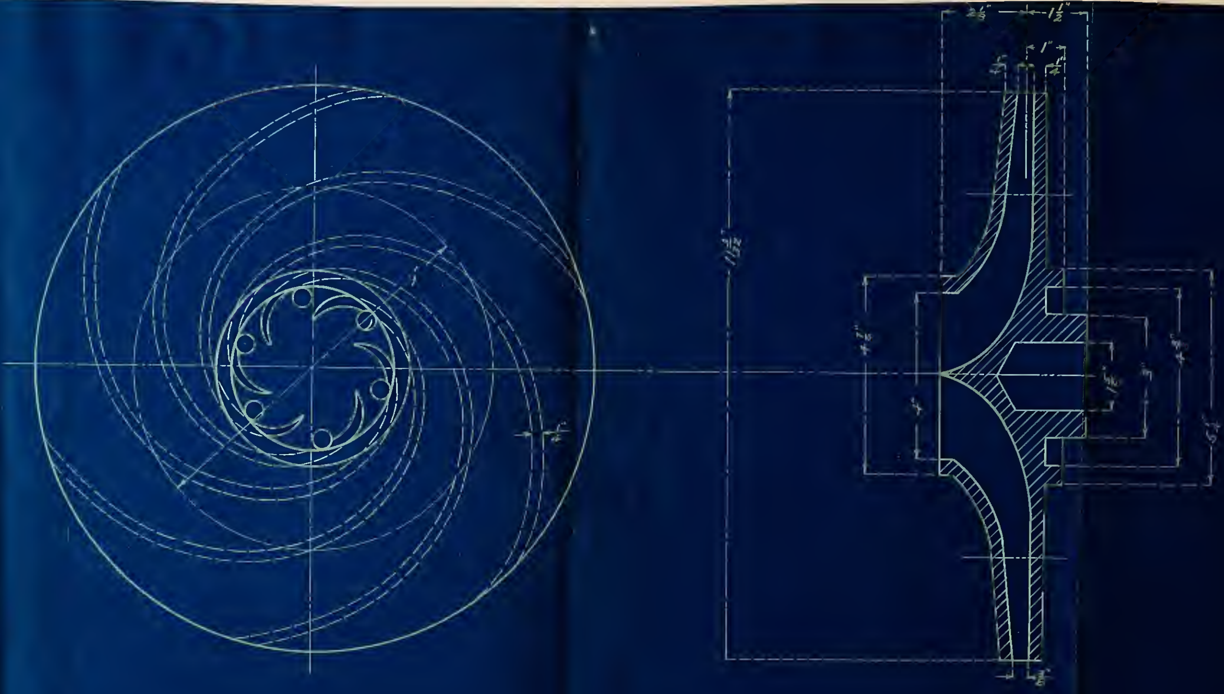

PLATE-3.
IMPELLER of PUMP

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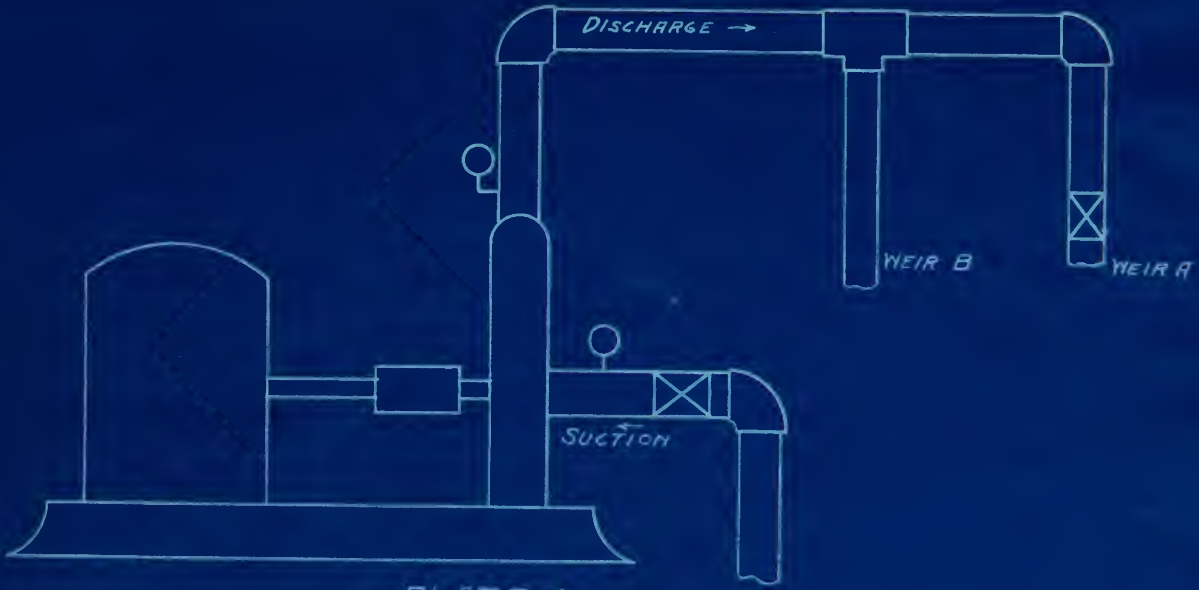

PLATE · 4.

GENERAL ARRANGEMENT OF APPARATUS.

Auxiliary Apparatus.

The motor used to drive the pump was built by the Electro Dynamie Co. of Bayome N. J. It develops ten horse power at eighty amperes and one hundred and ten volts and has a speed variation from two hundred and seventy five to twelve hundred revolutions per minute.

A voltmeter and ammeter calibrated for the purpose were used to indicate the potential difference and magnitued of the current at the terminals of the motor. The speed of the motor was measured by a tachmeter. The discharge pressure up to thirty pounds per square inch was measured by a three and one half inch Bourdon steam gauge #608R792. While for pressures above thirty pounds per square inch a one hundred and sixty pound per square inch Bourdon gauge was used. The suction head was measured by a three and one half inch Bourdon vacuum gauge, reading in inches of mercury.

At first it was intended to measure the water by an inch and a quarter Venturi meter in the discharge line. This method could not be used because the friction introduced in the meter prevented the discharge pressure from falling below eight pounds per square inch. Since this greatly shortened the range of investigation, it was decided to measure the water by means of weir notches.

The weir boxes used were of such dimensions as to give perfect contraction for notches not larger than twelve inches. In order to measure the larger discharges two weirs were placed in parallel (as shown in plate 5). The ten inch notch is marked A, while B is the twelve inch notch.

Calibration of Instruments.

Before starting the tests all the apparatus was carefully and accurately calibrated.

The pressure gauges were calibrated by a pressure gauge tester, while the vacuum gauge was calibrated by a comparison with the mercury column on a condenser. The calibration curves for the gauges are given on plate 5.

The ammeter and voltmeter were calibrated in the electrical laboratory by comparison with standard instruments. Their calibration curves are given on plate 6.

The tachometer was calibrated by comparison with a frequency meter, attached to a variable speed motor, that was fitted with a slip-rings so as to give alternating current. The tachometer had four separate scales upon it; namely 30-120, 100-400, 300-1200 and 1000-4000 revolutions per minute. However, only the 300-1200 and 100-400 scale were calibrated.

The calibration curves for the tachometer are given on plate 7.

In order to calibrate the motor it was disconnected from the pump and a pulley placed on the shaft. A prony brake was mounted on the pulley and complete calibrations were made for every three notches on the starting box. The power imput was secured from the scale readings brake arm and speed of the motor. The calibration curves for the motor are given in the calculating diagram (4).

The weir notches were calibrated both by the equation $Q\ 2/3\ C\quad 2g\ 6\ (H\ 1.\quad 4h)$, in which Merriman's coefficients were used; and also by weighing the water for short runs at different heads over the notch. These two methods checked very closely on each other and the calibration curves for each weir are given in the calculating diagram (4).

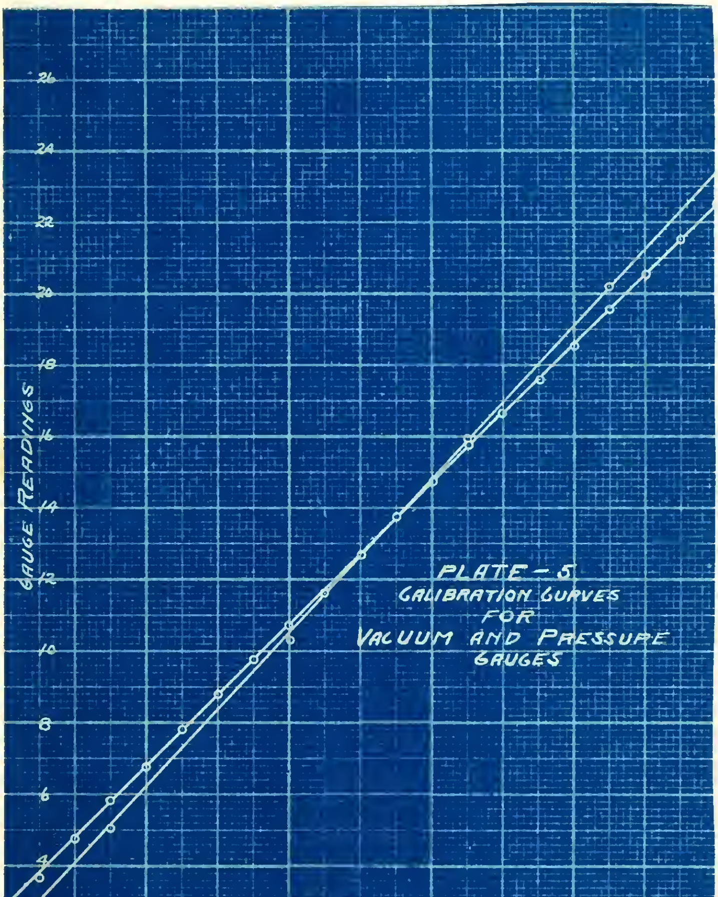

PLATE – 5
CALIBRATION CURVES
FOR
VACUUM AND PRESSURE
GAUGES

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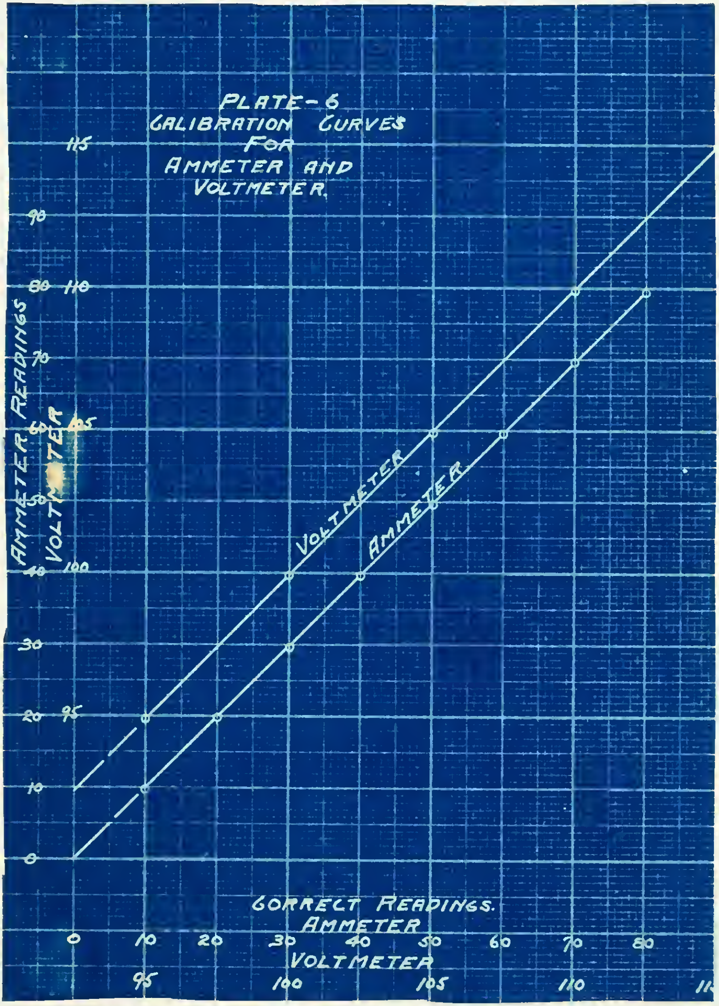

PLATE-6
CALIBRATION CURVES
FOR
AMMETER AND
VOLTMETER.

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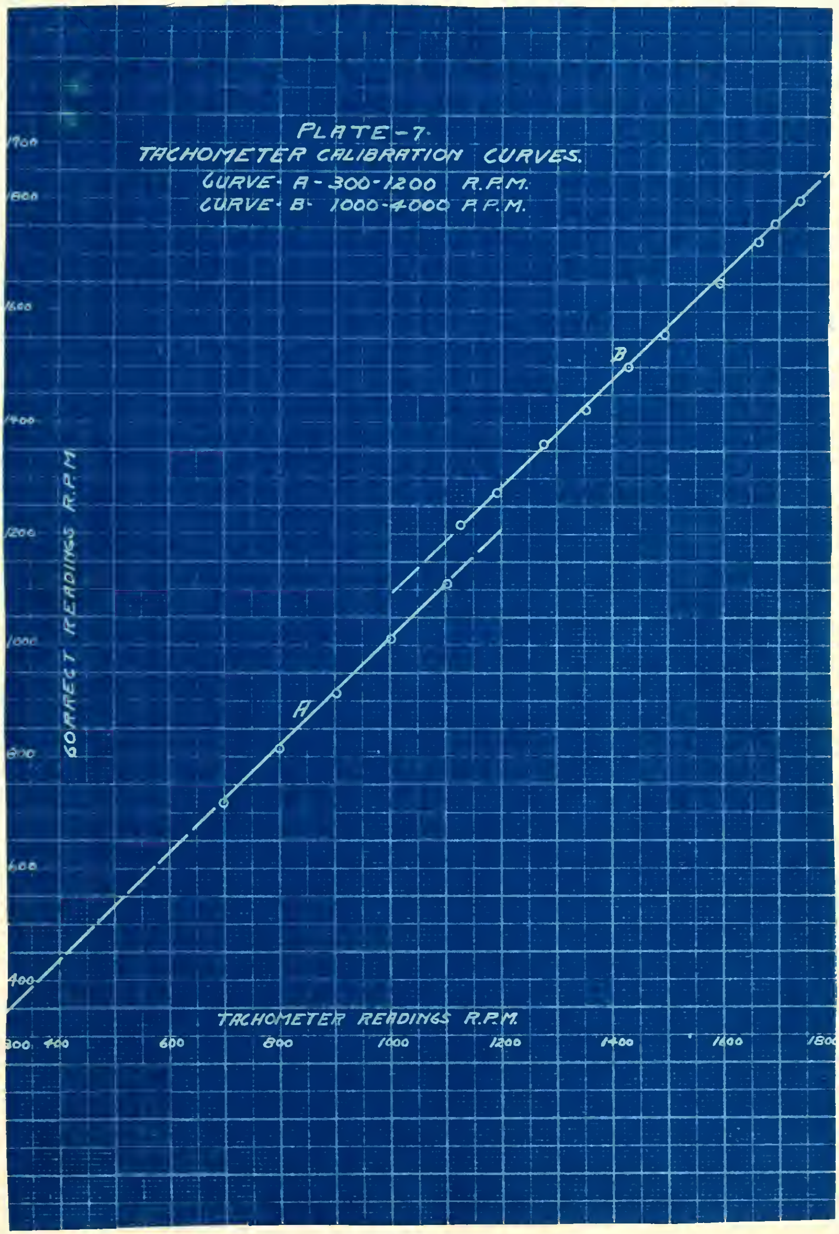

PLATE-7.
TACHOMETER CALIBRATION CURVES.
CURVE- A - 300-1200 R.P.M.
CURVE- B- 1000-4000 R.P.M.

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Characteristic of a Pump.

After the calibration of the instruments the pump was arranged in working order as shown in plate 5, and a complete test was made under working conditions at the speed specified by the maker to determine the characteristic and working efficiency of the pump.

It is worth while at this time to explain the meaning of the term characteristic as applied to the head against capacity curve of a centrifugal pump.

When a pump has a positive displacement action, its capacity is independent of the pressure against which it acts. It simply replaces the water by moving solid to which the necessary amount of pressure is applied.

In the case of the centrifugal pump, however, any change in capacity carries with it a definite change in head.

A certain rate of discharge at a given speed must have its specific head, whether we need it or not. This peculiar property of the centrifugal pump is termed its characteristic and is represented by the head-capacity curve, the shape of which depends upon the curvature of the impeller blades in the pump.

Testing Data and Results.

Table 1 is the running log for the first test. The number of observations for each condition were taken at regular intervals after the operation of the pump had become more or less uniform.

Table 2 gives the average corrected data and computed results for the first test, The method of calculating these results by means of a specially designed diagram is shown at the end of this work, where a sample calculation is carried thru.

Plate 8 gives the diagramatic representation of table 2. All the important items of the test are plotted against, the capacity in gallons per minute. It will be noticed that the suction curve rises too fast with the increase in capacity, and since the suction valve was left wide open during the test it seemed to be against all probabilities that the friction in a short length of four inch pipe with

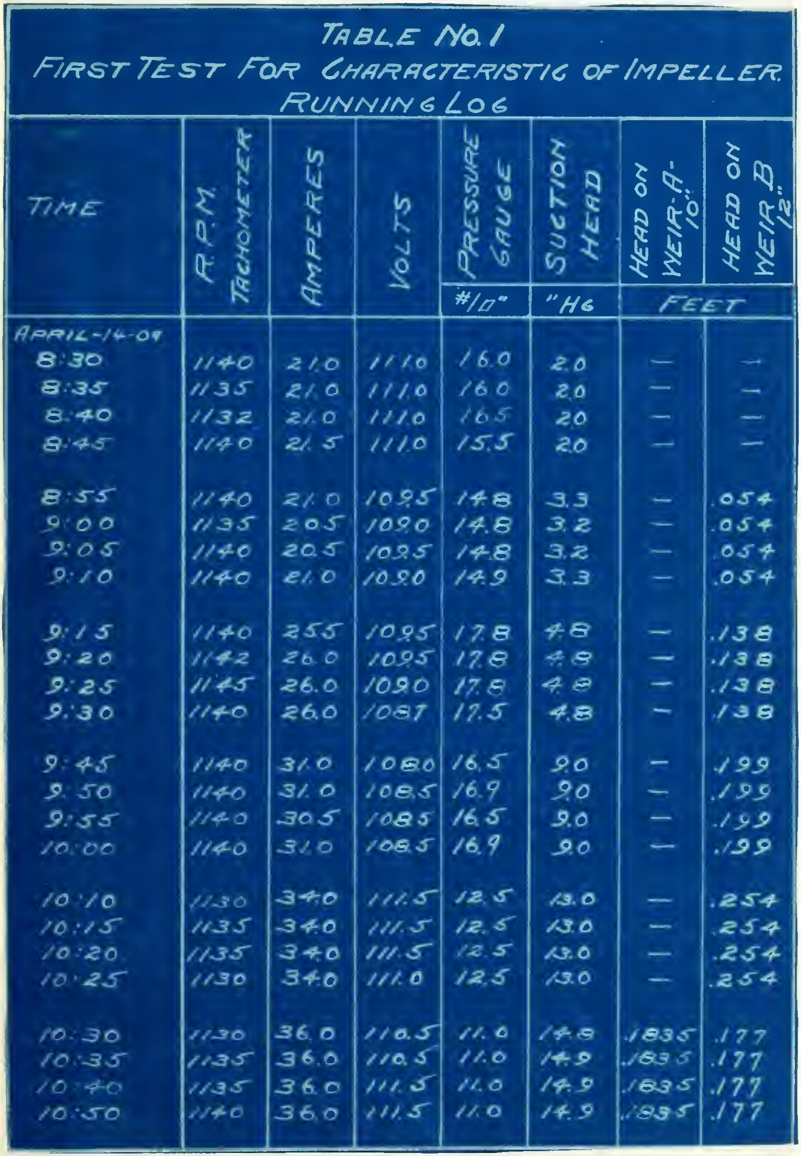

TABLE NO. 1
FIRST TEST FOR CHARACTERISTIC OF IMPELLER.
RUNNING LOG

TIME	R.P.M. TACHOMETER	AMPERES	VOLTS	PRESSURE GAUGE	SUCTION HEAD	HEAD ON WEIR-A-10"	HEAD ON WEIR-B 12"
				#/□"	"HG	FEET	
APRIL-14-09							
8:30	1140	21.0	111.0	16.0	2.0	—	—
8:35	1135	21.0	111.0	16.0	2.0	—	—
8:40	1132	21.0	111.0	16.5	2.0	—	—
8:45	1140	21.5	111.0	15.5	2.0	—	—
8:55	1140	21.0	109.5	14.8	3.3	—	.054
9:00	1135	20.5	109.0	14.8	3.2	—	.054
9:05	1140	20.5	109.5	14.8	3.2	—	.054
9:10	1140	21.0	109.0	14.9	3.3	—	.054
9:15	1140	25.5	109.5	17.8	4.8	—	.138
9:20	1142	26.0	109.5	17.8	4.8	—	.138
9:25	1145	26.0	109.0	17.8	4.8	—	.138
9:30	1140	26.0	108.7	17.5	4.8	—	.138
9:45	1140	31.0	108.0	16.5	9.0	—	.199
9:50	1140	31.0	108.5	16.9	9.0	—	.199
9:55	1140	30.5	108.5	16.5	9.0	—	.199
10:00	1140	31.0	108.5	16.9	9.0	—	.199
10:10	1130	34.0	111.5	12.5	13.0	—	.254
10:15	1135	34.0	111.5	12.5	13.0	—	.254
10:20	1135	34.0	111.5	12.5	13.0	—	.254
10:25	1130	34.0	111.0	12.5	13.0	—	.254
10:30	1130	36.0	110.5	11.0	14.8	.1835	.177
10:35	1135	36.0	110.5	11.0	14.9	.1835	.177
10:40	1135	36.0	111.5	11.0	14.9	.1835	.177
10:50	1140	36.0	111.5	11.0	14.9	.1835	.177

TABLE No. 1.
FIRST TEST FOR CHARACTERISTIC OF IMPELLER
RUNNING LOG - CONT.

TIME	R.P.M. TACHOMETER	AMPERES	VOLTS	PRESSURE GAUGE	SUCTION HEAD	HEAD ON WEIR A 10"	HEAD ON WEIR B 12"
				#/□"	"HG	FEET.	
APRIL-14-08							
10:50	1125	38.5	108.0	4.0	18.1	.183.5	.205
10:55	1135	38.5	108.5	4.0	18.1	.183.5	.205
11:00	1130	38.0	109.5	3.9	18.1	.183.5	.205
11:05	1140	38.0	109.5	3.9	18.1	.183.5	.205
11:15	1160	39.5	112.5	1.5	18.5	.250.5	.133
11:20	1180	40.5	112.0	1.5	18.8	.250.5	.133
11:25	1150	38.0	112.0	1.5	18.5	.250.5	.133
11:30	1145	38.0	112.5	1.5	18.4	.250.5	.133
1:10	1160	38.0	112.8	3.0	18.2	.1815	.200
1:15	1160	37.5	113.0	3.0	18.0	.1815	.200
1:20	1160	37.5	112.5	3.0	18.0	.1815	.200
1:25	1160	37.5	112.5	3.0	18.0	.1815	.200
1:50	1150	36.5	113.0	11.0	15.8	.181.5	.183
1:55	1150	37.0	113.0	11.0	15.8	.181.5	.183
2:00	1150	36.0	113.0	11.0	15.8	.1815	.183
2:05	1150	35.5	113.0	11.0	15.8	.1815	.183
2:15	1140	31.5	113.0	15.0	11.0	—	.227
2:20	1140	31.5	113.0	15.0	11.0	—	.227
2:25	1150	32.0	113.0	15.0	11.0	—	.227
2:30	1140	31.5	113.0	15.0	11.0	—	.227

DATE	RATIOS AND EFFICIENCIES				
	TOTAL HEAD TO PER. VEL. HEAD	SUCTION HEAD TO TOTAL HEAD	REJECTED HEAD TO TOTAL HEAD	NET EFFIC'Y OF PUMP.	PERCENT REALIZED IN DISCHARGE LIFT.
APRIL-14-09	87.2	4.25	0	0	0
	102	9.5	.4	36.7	33.6
	105.5	18.1	1.13	52	42.6
	95	30.2	2.5	59.8	41.8
	89.5	34.5	3.1	58.5	36.3
	60.5	68.2	5.9	43	9.0
	50.6	83.5	7.5	35.8	6.0
	57.2	71.5	5.8	39	11.1
	95.2	37.3	3.0	61.7	24.4
	102.5	23.4	1.66	59.4	41.5

TABLE NO. 2.
FIRST TEST FOR CHARACTERISTIC OF IMPELLER
CORRECTED DATA AND RESULTS.

DATE	TIME	R.P.M.	VELOCITY IN FEET PER SEC.		CAPACITY					HEADS IN FEET OF WATER.					POWER					RATIOS AND EFFICIENCIES				
					CU. FT. PER SEC.								VEL. EQUIVL'T											
			PERIPHERAL	WATER IN DISCHARGE PIPE	WEIR A	WEIR B	TOTAL	GALLONS PER MIN.	100 POUNDS PER HOUR	SUCTION	DISCHARGE	TOTAL	PERIPHERAL	DISCHARGE PIPE	VOLTS	AMPERES	WATTS IMPUT	NET HORSE POWER APPLIED TO PUMP	PUMP H.P.	TOTAL HEAD TO PER. VEL. HEAD	SUCTION HEAD TO TOTAL HEAD	REJECTED HEAD TO TOTAL HEAD	NET EFFIC'Y OF PUMP.	PERCENT REALIZED IN DISCHARGE LIFT.
APRIL-14-09	8:30-8:45	CONSTANT AT 1160.	CONSTANT AT 55.85	0	0	0	0	0	0	1.8	39.0	42.3	CONSTANT AT 48.5	0	111.5	20.6	2370	2.2	0	87.2	4.25	0	0	0
	9.15-9.30			3.55	0	.182	.182	81.9	409.5	4.7	43.3	49.5		.196	111.4	25.3	2880	2.78	1.02	102	9.5	.4	36.7	33.8
	9.45-10.00			6.10	0	.311	.311	140.	700	9.3	40.5	51.3		.578	111.4	29.6	3380	3.31	1.72	105.5	18.1	1.13	52	42.6
	10:10-10:25			8.6	0	.443	.443	200	1000	13.9	30.7	46.1		1.15	110.7	36.0	3850	3.8	2.27	.95	30.2	2.5	59.8	41.8
	10:30-10:45			9.3	.214	.263	.477	215	1075	15	27	43.5		1.35	110.2	39.8	4060	4.02	2.35	89.5	34.5	3.1	58.5	38.3
	10.50-11.05			10.5	.214	.324	.538	240	1210	20	7.8	29.3		1.72	109.4	38.4	4200	4.17	1.79	60.5	68.2	5.9	43	9.0
	11:15-11:30			10.9	.214	.346	.560	252	1260	20.5	2.6	24.5		1.85	112.6	40.4	4420	4.39	1.57	50.6	83.5	7.5	35.8	6.0
	1:10-1:25			10.2	.211	.313	.524	236	1179	19.9	6.4	27.8		1.61	113.0	38.0	4300	4.26	1.66	57.2	71.5	5.8	39	11.1
	1:50-2:05			9.45	.211	.275	.486	219	1093.5	17.3	27.5	46.3		1.40	113.4	36.7	4160	4.12	2.54	95.2	37.3	3.0	61.7	24.4
	2:15-2:30			7.3	0	.376	.376	169.2	846	11.7	36.7	49.9		.83	113.4	32.1	3640	3.59	2.13	102.5	23.4	1.66	59.4	41.5

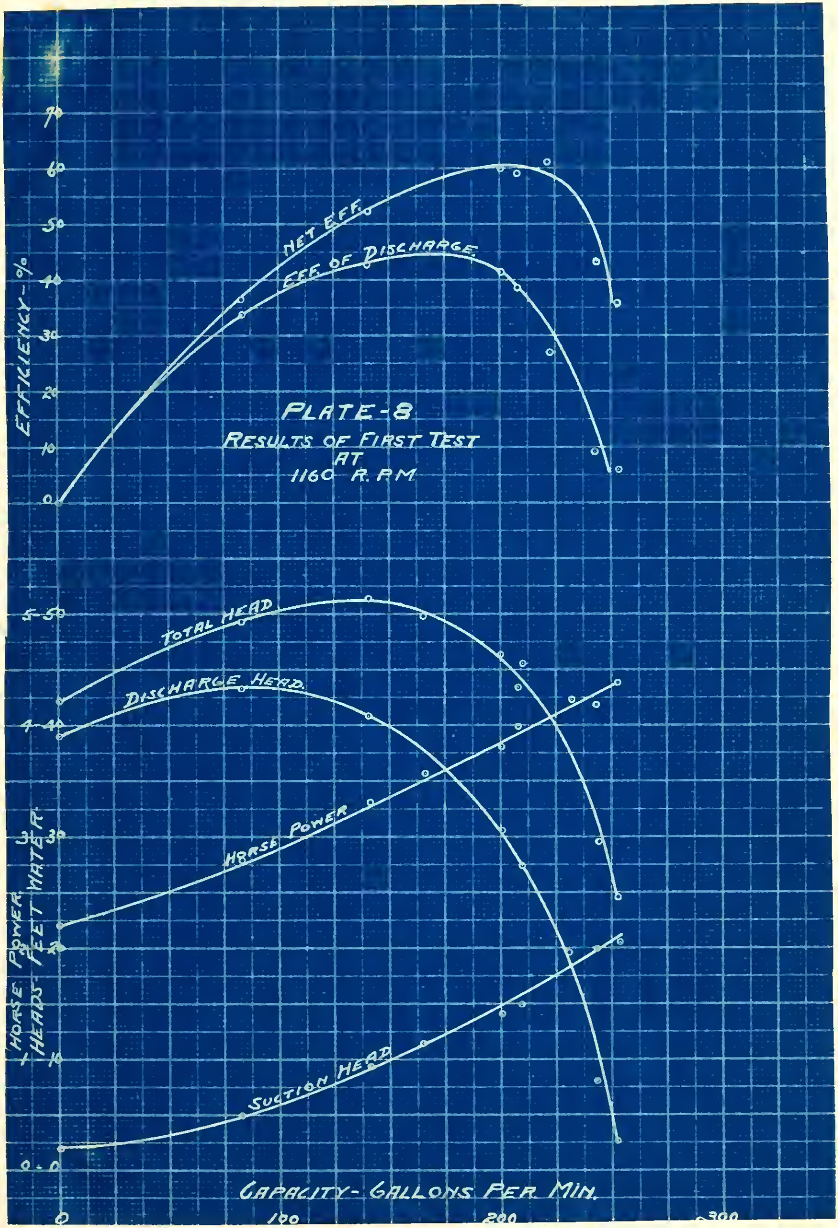
PLATE - 8
RESULTS OF FIRST TEST
AT
1160 R.P.M
NET EFF.
EFF. OF DISCHARGE.
TOTAL HEAD
DISCHARGE HEAD.
HORSE POWER
SUCTION HEAD
EFFICIENCY - %
HORSE POWER - HEADS - FEET WATER
CAPACITY - GALLONS PER MIN.
70
60
50
40
30
20
10
0
5-50
4-40
3 30
20
10
0 - 0
0
100
200
300

a couple of fittings would ever amount to a head of twenty-one feet of water, while the same quantity discharging thru a three inch pipe with an equal number of fittings was only two and one half feet against twenty-one feet of suction.

The cause was at first attributed to the strainer on the foot valve, having too small an inlet area. But the removal of the strainer showed no appreciable change in the operation of the pump.

After a close examination of the foot valve it was found that when the flap disc was opened wide it struck the bottom of the suction pipe and almost entirely covered the opening leaving only a small crescent shaped passage for the water. The foot valve was then removed and an extension put on so as to give the flap plenty of room.

The second test was made at the same speed and working conditions as the previous one in order to investigate the effect of

changing the foot valve.

Table 3 shows the running log, and table 4 the corrected data and results of the second test. The change produced in the operation of the pump is illustrated by the curves (plates 9, 10 and 8) in two ways.

At first considering the unnecessary suction head as a waste of energy the true efficiency of the pump was determined and a curve plotted below the net efficiency curve, for each test. It is plain that the relative difference between the two efficiency curves for each test represents the percent of energy spent in suction. This difference is very large in test 1 and quite small in the second test, showing that the extension to the foot valve increased the capacity of the pump.

In order more fully to illustrate the conditions of both tests, the curves of each test were plotted together on plate 10. The effect produced by the change is apparent at first sight.

TABLE No. 3
SECOND TEST FOR CHARACTERISTIC OF IMPELLER
RUNNING LOG.

TIME	R.P.M. TACHOMETER	AMPERES	VOLTS	PRESSURE GAUGE	SUCTION HEAD	HEAD ON WEIR A 10"	HEAD ON WEIR B 12"
				#/□"	"HG	FEET	
APRIL-23-09							
9:00	1140	19.0	111.5	16.5	3	—	—
9:05	1140	19.0	111.5	16.0	3	—	—
9:10	1136	19.0	111.0	16.0	3	—	—
9:15	1140	19.0	111.0	15.5	3	—	—
9:25	1140	23	111	17.7	3	—	.099
9:30	1140	23	111	17.8	3	—	.099
9:35	1142	23	111	18.0	3	—	.099
9:40	1142	23	111	18.0	3	—	.099
10:00	1150	26	111	19.1	3.1	—	.141
10:05	1150	26	111	19.1	3.1	—	.141
10:10	1150	26	111	19.1	3.1	—	.141
10:15	1150	26.5	111	19.1	3.1	—	.141
10:20	1130	30.5	110.5	18.9	3.5	—	.195
10:25	1135	30.5	110.5	18.9	3.5	—	.195
10:30	1140	30.0	110.5	18.9	3.5	—	.195
10:35	1150	32.0	110.0	19.0	3.5	—	.195
10:45	1140	33.	110	18.3	4	—	.238
10:50	1135	34	110	18.7	4	—	.238
10:55	1140	34	110	18.7	4	—	.238
11:00	1150	34	110	18.7	4	—	.238

TABLE No. 3.
SECOND TEST FOR CHARACTERISTIC OF IMPELLER
RUNNING LOG CONT.

TIME	R.P.M. TACHOMETER	AMPERES	VOLTS	PRESSURE GAUGE #/□"	SUCTION HEAD "HG	HEAD ON WEIR A 10" FEET	HEAD ON WEIR B 12" FEET
APRIL-23-09							
11:10	1130	35.0	109.5	17.0	4.2	.148	.191
11:15	1140	36.0	109.0	17.2	4.2	.148	.191
11:20	1130	35.5	109.5	17.2	4.2	.148	.191
11:25	1140	36.0	109.5	17.5	4.4	.148	.191
11:35	1145	38	110.	16.0	4.6	.175	.202
11:40	1140	39	110.	16.0	4.8	.175	.202
11:45	1140	36	110	15.2	4.5	.175	.202
11:50	1135	38	110.	15.6	4.8	.175	.202
12:00	1140	41	110	9.5	6.1	.221	.241
12:05	1130	43	110	9.5	6.1	.221	.241
12:10	1130	40	110	9.5	6.2	.221	.241
12:15	1130	42	110	9.5	6.1	.221	.241
12:20	1110	40	110	3	7.2	.321	.180
12:25	1120	40	110	3	7.2	.321	.180
12:30	1120	40	110	3	7.2	.321	.180
12:35	1110	40	110	3	7.2	.321	.180
12:50	1140	44	110	7	7	.200	.270
12:55	1140	43	110	7	7	.200	.270
1:00	1140	44	110	7	7	.200	.270
1:05	1140	41	110	7	7	.200	.270

	RATIOS AND EFFICIENCIES.				
PUMP H.P.	TOTAL HEAD TO PER. VEL. HEAD	SUCTION HEAD TO TOTAL HEAD	REJECTED HEAD TO TOTAL HEAD	NET EFFIC'Y OF PUMP	PERCENT REALIZED IN DISCHARGE LIFT
0	89.5	6.7	0	0	0
15	99.2	6.05	.173	25	23.5
12	107	5.7	.405	39.3	37.
51	105	6.7	1.07	47.6	44.4
.31	104	7.7	1.87	62.8	58
44	98.1	8.8	2.56	62.2	56.7
62	91.5	10.35	3.58	61.0	53.7
38	63.3	19.8	9.1	52.0	41.7
34	32.6	46.	21.4	31.8	17.2
12	52.1	28	12.4	44.2	31.8

TABLE NO. 4

SECOND TEST FOR CHARACTERISTIC OF IMPELLER
CORRECTED DATA AND RESULTS

			VELOCITY IN FEET PER SEC.		CAPACITY					HEADS IN FEET OF WATER					POWER					RATIOS AND EFFICIENCIES.				
					CU. FT. PER SEC.								VEL. EQUIVL'T											
DATE	TIME	R.P.M.	PERIPHERAL	WATER IN DISCHARGE PIPE	WEIR A	WEIR B	TOTAL	GALLONS PER MIN.	100 POUNDS PER HOUR	SUCTION	DISCHARGE	TOTAL	PERIPHERAL	DISCHARGE PIPE	VOLTS	AMPERES	WATTS IMPUT	NET HORSE POWER APPLIED TO PUMP	PUMP H.P.	TOTAL HEAD TO PER. VEL. HEAD	SUCTION HEAD TO TOTAL HEAD	REJECTED HEAD TO TOTAL HEAD	NET EFFICIENCY OF PUMP	PERCENT REALIZED IN DISCHARGE LIFT
APRIL-23-02	9:00-9:15	CONSTANT AT 1160	CONSTANT AT 55.85	0	0	0	0	0	0	2.9	39	43.4	CONSTANT AT 48.6	0	111.5	19.1	2110	1.92	0	89.5	6.7	0	0	0
	9:25-9:40			2.3	0	.113	.113	51	255	2.9	43.6	48.0		.083	111.4	23.2	2580	2.46	.615	99.2	6.05	.173	25	23.5
	10:00-10:15			3.7	0	.188	.188	84.6	423	3.0	48	52.5		.213	111.4	26.4	2940	2.84	1.12	107.	5.7	.405	39.3	37.
	10:20-10:35			5.9	0	.302	.302	136	680	3.4	46	50.9		.545	110.7	31.2	3450	3.17	1.51	105	6.7	1.07	47.6	44.4
	10:45-11:00			7.8	0	.402	.402	181	905	3.9	45.3	50.7		.95	110.2	33.8	3730	3.68	2.31	104	7.7	1.87	62.8	58
	11:10-11:25			8.8	.160	.292	.452	203	1015	4.2	42	47.7		1.22	109.7	36.1	3960	3.92	2.44	98.1	8.8	2.56	62.2	56.7
	11:35-11:50			10.1	.201	.318	.519	233.5	1167.5	4.6	38.4	44.5		1.59	110.2	38.6	4260	4.33	2.62	91.5	10.35	3.55	61.0	53.7
	12:00-12:15			13.4	.277	.410	.687	309	1545	6.1	23.1	30.7		2.8	110.5	41.8	4620	4.59	2.38	63.3	19.8	9.1	52.0	41.7
	12:20-12:35			14.7	.482	.269	.751	338	1690	7.3	7.0	15.8		3.38	110.5	40.4	4460	4.23	1.34	32.6	46	21.4	31.8	17.2
	12:50-1:05			14.2	.241	.485	.726	327	1635	7.1	16.7	25.3		3.13	110.3	43.6	4830	4.80	2.12	52.1	28	12.4	44.2	31.8

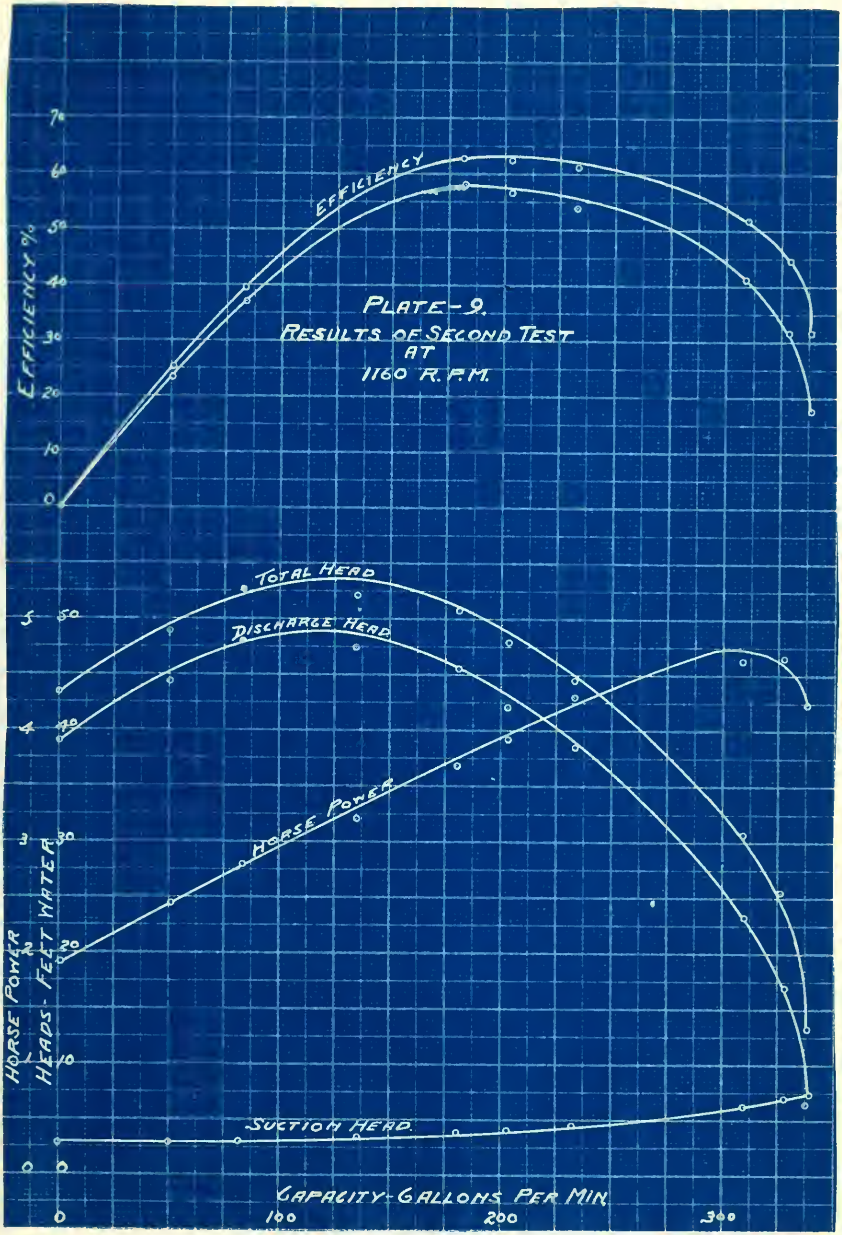

PLATE-9.
RESULTS OF SECOND TEST
AT
1160 R.P.M.

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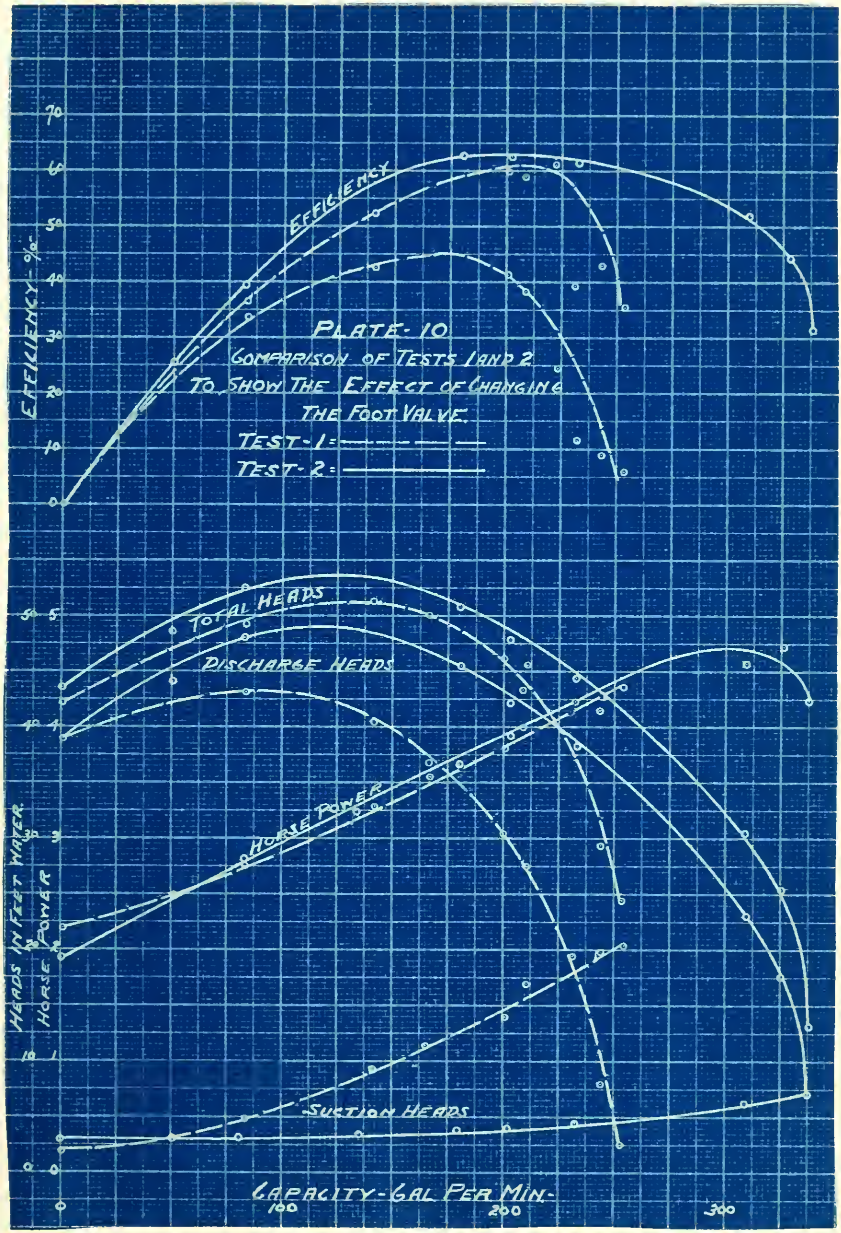

PLATE-10
COMPARISON OF TESTS 1 AND 2
TO SHOW THE EFFECT OF CHANGING
THE FOOT VALVE.

It will be noticed that while the horse power curves are almost identical in both cases the range of capacity and area covered by the efficiency curve are more than fifty percent larger in the second test.

The third test was performed in order to analyze the effect of throttling the suction at the same speed of the previous tests. It was noticed that the characteristic curve could not be started from a zero discharge, owing to the leakage of air past the fittings. The run was then started from the other end of the curve.

The pump was started and both the suction and discharge valves were opened wide. The suction was then gradually throttled and observations were made for each point. The suction wes throttled until the pump dropped the vacuum. The vacuum was picked up again and kept at about twenty-five feet of water, while the discharge pressure was increased by regular intervals until the vacuum again fell off.

TABLE No. 5

TEST FOR THE EFFECT OF THROTTLING SUCTION.

RUNNING LOG.

TIME	R.P.M. TACHOMETER	AMPERES	VOLTS	PRESSURE GAUGE	SUCTION HEAD	HEAD ON WEIR A 10"	HEAD ON WEIR B 12"
				#/□"	"Hg	FEET	
APRIL-23-09							
1:20	1130	45.5	110	2.	7.8	.238	.253
1:25	1140	45.5	110	2.	7.8	.238	.253
1:30	1140	45.5	110	2.	7.9	.238	.253
1:35	1130	45.0	110	2.	7.8	.238	.253
1:45	1140	45.0	109.5	1.5	10.2	.227	.250
1:50	1140	44.0	110.	1.7	10.0	.227	.250
1:55	1140	44.0	110.	1.7	10.2	.227	.250
2:00	1140	44.0	110.	1.7	10.2	.227	.250
2:05	1135	42.0	109.5	1.4	15.0	.202	.242
2:10	1140	42.0	109.5	1.4	15.0	.202	.242
2:15	1135	42.0	110.0	1.4	15.0	.202	.242
2:20	1140	42.0	109.5	1.4	15.0	.202	.242
2.25	1135	40.0	110	1.1	19.0	.170	.236
2.30	1130	39.5	110	1.1	19.0	.170	.236
2.35	1130	39.0	110	1.1	19.0	.170	.236
2.40	1130	39.5	110	1.1	19.0	.170	.236
2.50	1125	36	110	1.0	22.0	—	.231
2.55	1130	36	110	1.0	22.0	—	.231
3:00	1135	36	110	1.0	22.0	—	.231
3:05	1130	36	110	1.0	22.0	—	.231

TABLE No. 5
TEST FOR EFFECT OF THROTTLING SUCTION
RUNNING LOG CONT.

TIME	R.P.M. TACHOMETER	AMPERES	VOLTS	PRESSURE GAUGE	SUCTION HEAD	HEAD ON WEIR A 10"	HEAD ON WEIR B 12"
				#/□"	"HG	FEET.	
APRIL 23-09							
3:10	1140	34.5	110.5	1.2	22	—	.286
3:15	1140	34.5	110.5	1.2	22	—	.286
3:20	1140	34.0	111.0	1.2	22	—	.286
3:25	1140	34.0	111.0	1.2	22	—	.286
3:30	1140	34.5	111	10.	22	—	.246
3:35	1145	35.0	111	10	22	—	.246
3:40	1140	34.5	111	10	22	—	.246
3:45	1145	34.5	111	10	22	—	.246
3:50	1142	30.0	113	10	22.5	—	.201
3:55	1145	30.0	113	10	22.5	—	.201
4:00	1140	30.0	113	10	22.0	—	.201
4:05	1137	29.5	113	10	22.0	—	.201
4:10	1137	25.0	113	7	22.0	—	.153
4:15	1141	25.5	113	6.5	23.0	—	.153
4:20	1145	25.5	113	6	22.3	—	.153
4:25	1140	25.5	113	5.5	23.0	—	.153
4:30	1133	22.5	113	3.5	22.0	—	.125
4:35	1135	23.0	113	3.0	22.0	—	.125
4:40	1130	23.0	113	3.0	22.0	—	.125
4:45	1137	23.0	113	3.0	22.0	—	.125

			RATIOS AND EFFICIENCIES			
IMPUT	NET HORSE POWER APPLIED TO PUMP.	PUMP H.P.	TOTAL HEAD TO PER VEL HEAD	SUCTION HEAD TO TOTAL HEAD	REJECTED HEAD TO TOTAL HEAD	NET EFFIC'Y OF PUMP.
70	5.02	1.22	29.8	64.1	22.6	24.3
10	4.88	1.26	31.	70.3	20.2	25.8
70	4.64	1.48	41.4	81.2	12.5	32.1
00	4.16	1.68	51	84.6	8.25	40.3
70	3.92	1.43	59.3	87	3.92	36.5
80	3.84	1.73	59.3	87	5.97	45
80	3.84	2.44	104.5	49.2	2.0	63.5
20	3.14	1.82	104.5	49.2	1.14	58
30	2.82	.99	65	60.5	.63	35
20	2.45	.60	68	75.8	.45	24.5

TABLE NO. 6

TEST FOR EFFECT OF THROTTLING SUCTION.
CORRECTED DATA AND RESULTS.

DATE	TIME	R.P.M.	VELOCITY IN FEET PER SEC.		CAPACITY					HEADS IN FEET OF WATER					POWER					RATIOS AND EFFICIENCIES			
					CU. FT. PER SEC.								VEL. EQUIVL'T.										
			PERIPHERAL	WATER IN DISCHARGE PIPE	WEIR A	WEIR B.	TOTAL	GALLONS PER MIN.	100 POUNDS PER HOUR.	SUCTION	DISCHARGE	TOTAL	PERIPHERAL	DISCHARGE PIPE	VOLTS	AMPERES	WATTS IMPUT	NET HORSE POWER APPLIED TO PUMP	PUMP H.P.	TOTAL HEAD TO PER VEL HEAD	SUCTION HEAD TO TOTAL HEAD	REJECTED HEAD TO TOTAL HEAD	NET EFFIC'Y OF PUMP
APRIL 23 [illegible]	1:20-1:35	CONSTANT AT 1160	CONSTANT AT 55.85	14.6	.308	.440	.748	336.5	1683	9.3	3.7	14.5	CONSTANT AT 48.6	3.27	110.2	46	5070	5.02	1.22	29.8	64.1	22.6	24.3
	1:45-2:00			14.0	.287	.433	.720	324	1620	10.6	3	15.1		3.05	110.1	44.6	4910	4.88	1.26	31.	70.3	20.2	25.8
	2:05-2:20			12.7	.244	.413	.657	295.5	1478	16.3	2.3	20.1		2.52	109.8	42.5	4670	4.64	1.48	41.4	81.2	12.5	32.1
	2:25-2:40			11.5	.193	.398	.591	266	1330	21	2.3	24.8		2.05	110.2	40	4400	4.16	1.68	51	84.6	8.25	40.3
	2:50-3:05			8.5	0	.438	.438	197	985	25	2.3	28.6		1.13	110.2	36.6	3970	3.92	1.43	59.3	87	3.92	36.5
	3:10-3:25			10.5	0	.528	.528	238	1190	25	2.3	28.8		1.72	111.	33	3880	3.84	1.73	59.3	87	5.97	45
	3:30-3:45			8.2	0	.423	.423	190	950	25	24.3	50.8		1.02	111.2	35	3880	3.84	2.44	104.5	49.2	2.0	63.5
	3:50-4:05			6.15	0	.315	.315	142	710	25	24.3	50.8		.58	113.3	30.2	3420	3.14	1.82	104.5	49.2	1.14	58
	4:10-4:25			4.1	0	.212	.212	95	475	25	14.8	41.3		.26	113.3	25.8	2930	2.82	.99	85	60.5	.63	35
	4:30-4:45			3.1	0	.158	.158	71	355	25	6.5	33.0		.15	113.3	23.1	2620	2.45	.60	68	75.8	.45	24.5

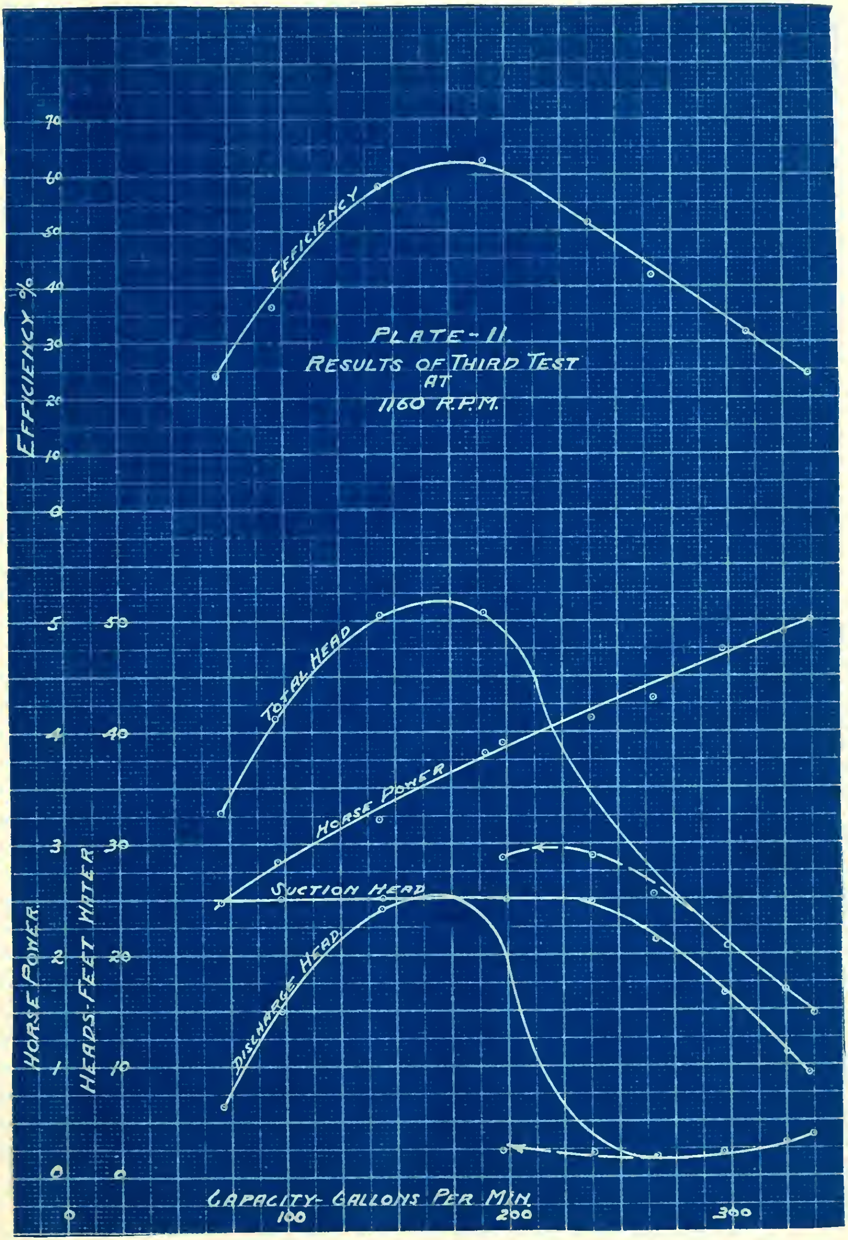

PLATE-II.
RESULTS OF THIRD TEST
AT
1160 R.P.M.

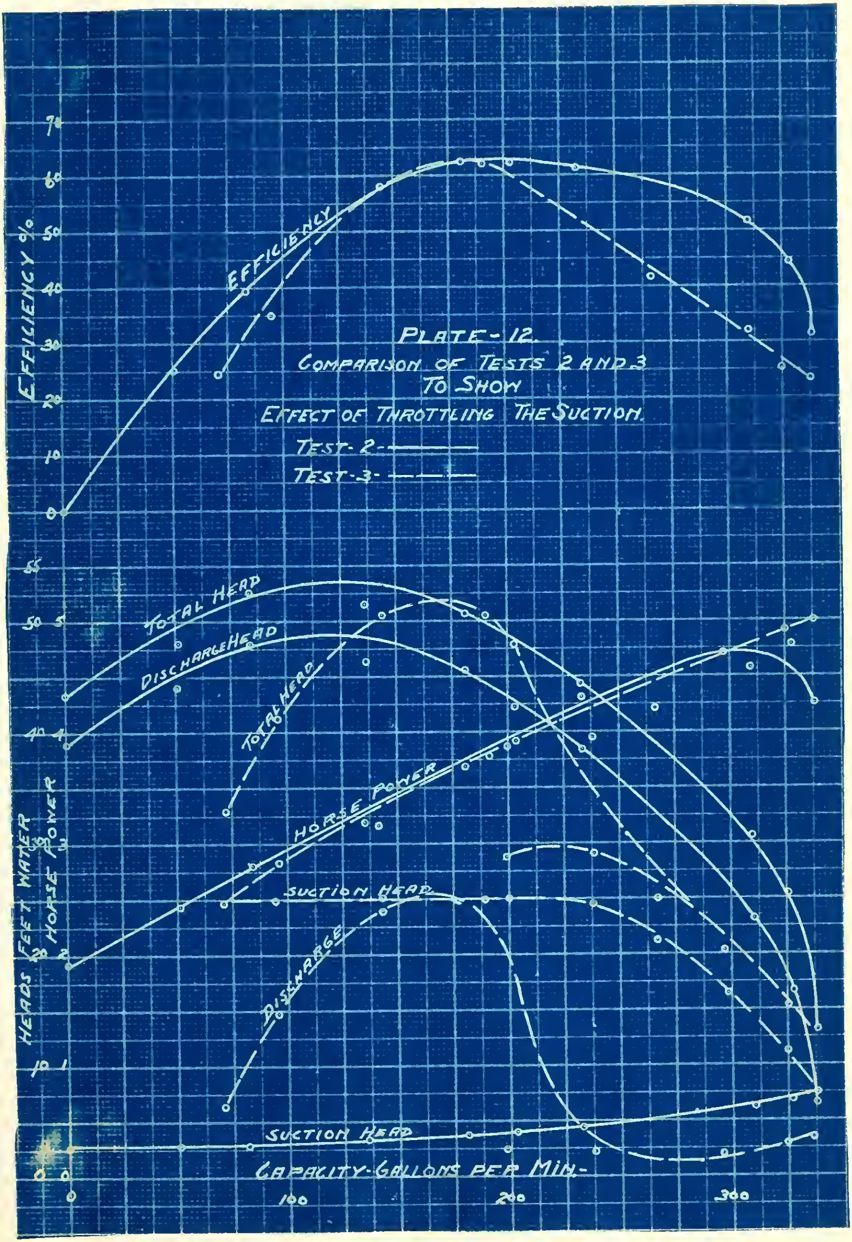

PLATE - 12.
COMPARISON OF TESTS 2 AND 3
TO SHOW
EFFECT OF THROTTLING THE SUCTION.

TEST - 2 ————
TEST - 3 — — — —

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[illegible]

As seen from the curves the effect of throttling the suction is to rapidly diminish the capacity while the efficiency rises very slowly.

A comparison of the second and third runs is given on plate 12. All indications seem to point to throttling the discharge. However, the horse power curve is somewhat smaller, for the same capacity in the third run than in the second.

Another test was made at the same speed but with a constant total head. The suction and discharge heads were varied from a maximum to a minimum, at the same time keeping the total head constant.

The running log for this test is in table 7 and the results in table 8. The curves are plotted on plate 13. In this test the capacity heads, horse power and efficiency are plotted against the percent of suction to total head.

TABLE NO. 7
TEST AT A CONSTANT TOTAL HEAD
RUNNING LOG.

TIME	R.P.M. TACHOMETER	AMPERES	VOLTS	PRESSURE GAUGE	SUCTION HEAD	HEAD ON WEIR A 10"	HEAD ON WEIR B 12"
				#/□"	"Hg	FEET	
APRIL·27·09							
9:20	1146	34.0	114	20	4	—	.234
9:25	1142	34.0	114	20	4	—	.234
9:30	1149	35.0	114	20	4	—	.234
9:35	1144	34.5	114	20	4	—	.234
9:45	1150	36.	113	18.7	7	—	.244
9:50	1147	35.5	113	18.8	7	—	.244
9:55	1145	36.	113	18.8	7	—	.244
10:00	1147	36	113	18.9	7	—	.244
10:05	1145	36	113	15	14	—	.249
10:10	1149	36	113	15	14	—	.249
10:15	1144	36	113	15	14	—	.249
10:20	1145	36	113	15	14	—	.249
10:25	1137	36.5	113	13	18	—	.246
10:30	1142	37.	113	13	18	—	.246
10:35	1139	36.5	113	13	18	—	.246
10:40	1140	37	113	13	18	—	.246
10:50	1135	35.0	113	11	22	—	.224
10:55	1140	34.5	113	11	22	—	.224
11:00	1142	35.0	113	11	22	—	.224
11:05	1143	34.5	113	11	22	—	.224

DATE	PUMP H.P.	RATIOS AND EFFICIENCY			
		TOTAL HEAD TO PER. VEL. HEAD.	SUCTION HEAD TO TOTAL HEAD	REJECTED HEAD TO TOTAL HEAD	NET EFFIC'Y OF PUMP.
APR.27-0	.28	106	7.75	1.74	57.8
	.46	107	13.6	2.34	60.8
	.49	105	29.5	2.28	60.5
	.46	105	38.8	2.04	58.8
	.15	106	47.8	1.53	54.5

TABLE NO. 8.
TEST AT CONSTANT TOTAL HEAD
CORRECTED DATA AND RESULTS

DATE	TIME	R. P. M.	VELOCITY IN FEET PER SEC.		CAPACITY					HEADS IN FEET OF WATER					POWER					RATIOS AND EFFICIENCY			
					CU. FT. PER SEC.								VEL. EQUIVL'T.										
			PERIPHERAL	WATER IN DISCHARGE PIPE	WEIR A	WEIR B	TOTAL	GALLONS PER MIN.	100 POUNDS PER HOUR.	SUCTION	DISCHARGE	TOTAL	PERIPHERAL	DISCHARGE PIPE	VOLTS	AMPERES	WATTS INPUT	NET HORSE POWER APPLIED TO PUMP.	PUMP H.P.	TOTAL HEAD TO PER VEL. HEAD.	SUCTION HEAD TO TOTAL HEAD	REJECTED HEAD TO TOTAL HEAD	NET EFFIC'Y OF PUMP.
APR. 27-09	9:20-9:35	CONSTANT-1160	55.85	7.6	0	.393	.393	177	885	4.0	46.2	51.7	48.6	.9	114.3	34.8	3960	3.95	2.28	106	7.75	1.74	57.8
	9:45-10:00			8.1	0	.418	.418	188	940	7.1	43.6	52.2		1.02	113.3	36.4	4120	4.09	2.46	107	13.6	2.34	60.8
	10:05-10:20			8.65	0	.430	.430	193.5	968	15.1	34.6	51.2		1.17	113.3	36.6	4150	4.12	2.49	105	29.5	2.28	60.5
	10:25-10:40			8.2	0	.423	.423	190	950	19.9	30.0	51.4		1.05	113.3	37.2	4220	4.19	2.46	105	38.8	2.04	58.8
	10:50-11:05			7.1	0	.368	.368	166	830	24.7	25.4	51.6		.79	113.3	35.3	4000	3.96	2.15	106	47.8	1.53	54.5

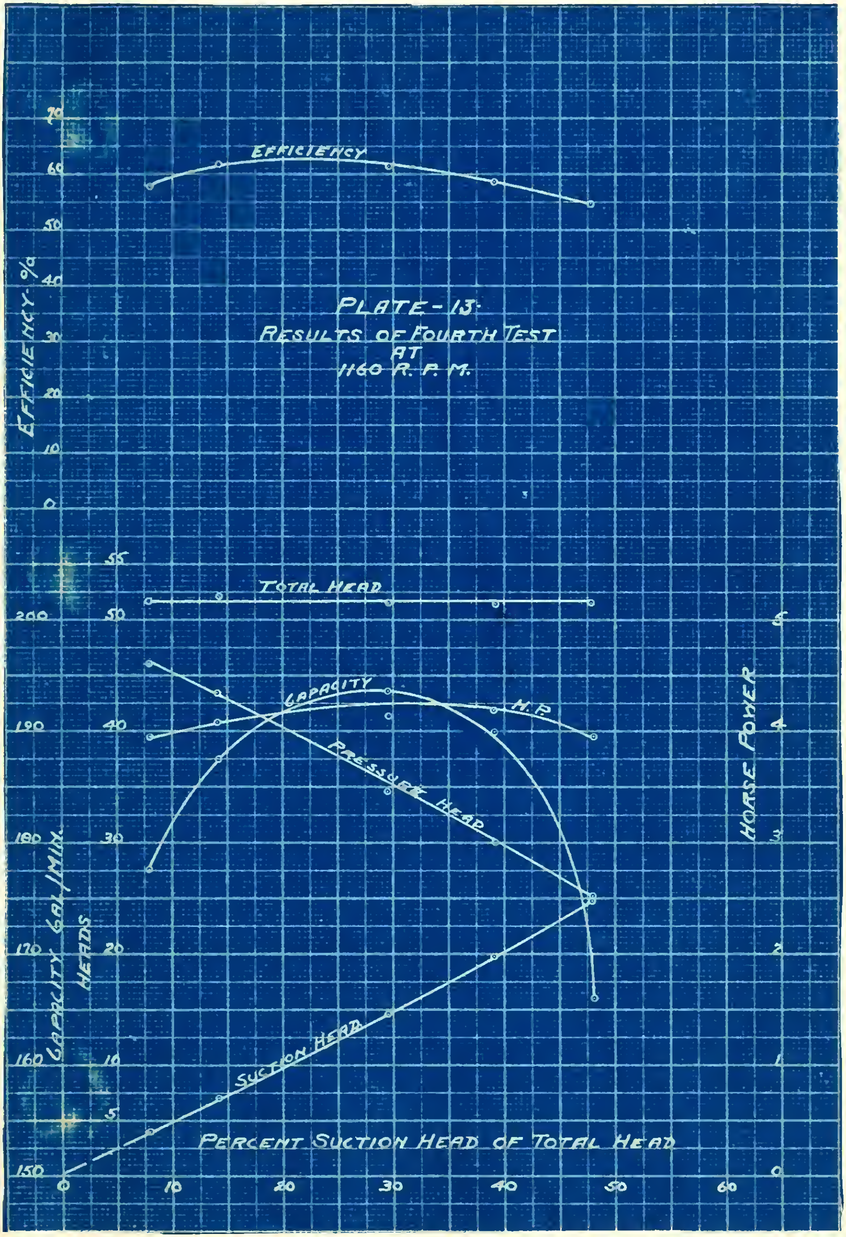
PLATE-13.
RESULTS OF FOURTH TEST
AT
1160 R.P.M.

The efficiency varies very little thruout the run being a maximum at one hundred and ninty-two gallons per minute and about twenty percent suction. A comparison with the efficiency curve of the second test, where maximum efficiency is at a capacity of about one hundred and ninty gallons per minute, but with only five percent suction. This shows that the main condition for high efficiency is the proper capacity and total head.

The investigation was continued on four more different speeds of the impeller. In each case the test was made a continuous run. First the characteristic was secured by throttling the discharge with the suction open, second with throttled suction, and third with a constant throttled suction and a throttled discharge.

The results and curves for a speed of eight hundred and fifty revolutions per minute are found in table 9 & 10- and plate 14. The

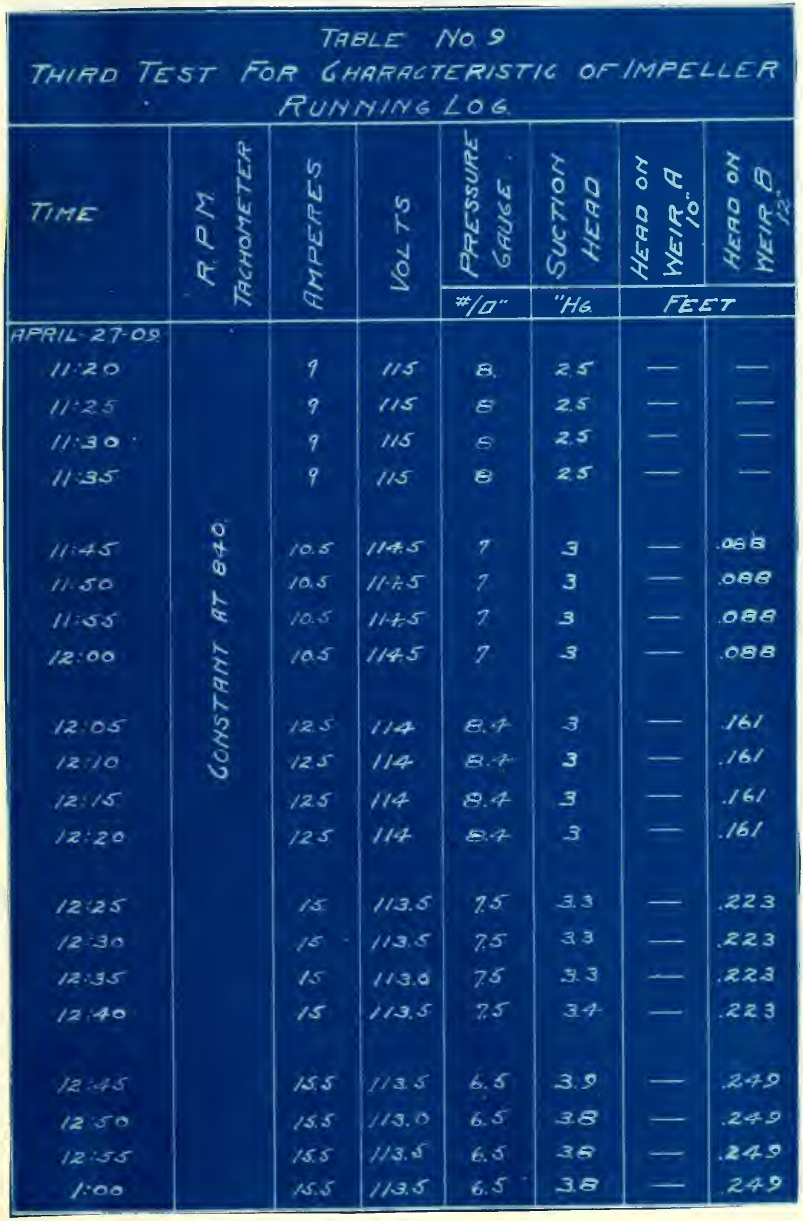

TABLE NO. 9
THIRD TEST FOR CHARACTERISTIC OF IMPELLER
RUNNING LOG.

TIME	R.P.M. TACHOMETER	AMPERES	VOLTS	PRESSURE GAUGE #/□"	SUCTION HEAD "HG.	HEAD ON WEIR A 10" FEET	HEAD ON WEIR B 12" FEET
APRIL-27-09.							
11:20	CONSTANT AT 840.	9	115	8.	2.5	—	—
11:25		9	115	8	2.5	—	—
11:30		9	115	8	2.5	—	—
11:35		9	115	8	2.5	—	—
11:45		10.5	114.5	7	3	—	.088
11:50		10.5	114.5	7	3	—	.088
11:55		10.5	114.5	7	3	—	.088
12:00		10.5	114.5	7	3	—	.088
12:05		12.5	114	8.4	3	—	.161
12:10		12.5	114	8.4	3	—	.161
12:15		12.5	114	8.4	3	—	.161
12:20		12.5	114	8.4	3	—	.161
12:25		15	113.5	7.5	3.3	—	.223
12:30		15	113.5	7.5	3.3	—	.223
12:35		15	113.0	7.5	3.3	—	.223
12:40		15	113.5	7.5	3.4	—	.223
12:45		15.5	113.5	6.5	3.9	—	.249
12:50		15.5	113.0	6.5	3.8	—	.249
12:55		15.5	113.5	6.5	3.8	—	.249
1:00		15.5	113.5	6.5	3.8	—	.249

TABLE NO. 9
THIRD TEST FOR CHARACTERISTIC OF IMPELLER
RUNNING LOG CONT.

TIME	R.P.M. TACHOMETER	AMPERES	VOLTS	PRESSURE GAUGE	SUCTION HEAD	HEAD ON WEIR A 10"	HEAD ON WEIR B 12"
				#/□"	"HG	FEET.	
APRIL 27-09							
1:10	CONSTANT AT 840	16.5	113.5	4.8	4	—	.281
1:15		16.5	113	4.5	4	—	.281
1:20		16.5	113.5	4.7	4	—	.281
1:25		16.5	113.5	4.7	4	—	.281
1:30		17	114	2	4.8	—	.320
1:35		17	113.5	2	4.8	—	.320
1:40		17	113.5	2	4.8	—	.320
1:45		17	113.5	2	4.8	—	.320
1:50		17	114	1.5	8.	—	.308
1:55		17	114	1.5	8.	—	.308
2:00		17	114	1.5	8.	—	.308
2:05		17	114	1.5	8	—	.308
2:10		17	114	1.3	12	—	.285
2:15		17	114	1.3	12	—	.285
2:20		17	114	1.3	12	—	.285
2:25		17	114	1.3	12	—	.285
2:30		16.5	114	1.1	15	—	.266
2:35		17.	113.5	1.1	15	—	.266
2:40		16.5	113.5	1.1	15	—	.266
2:45		16.5	113.5	1.1	15	—	.266

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TABLE NO. 9
THIRD TEST FOR CHARACTERISTIC OF IMPELLER
RUNNING LOG. CONT.

TIME	R.P.M. TACHOMETER	AMPERES	VOLTS	PRESSURE GAUGE	SUCTION HEAD	HEAD ON WEIR A 10"	HEAD ON WEIR B 12"
				#/□"	" HG	FEET	
APRIL-27-09							
3:00	CONSTANT AT 840	16	113.5	1	18	—	.239
3:05		16	114	1	18	—	.239
3:10		16	114	1	18	—	.239
3:15		16	114	1	18	—	.239
3:20		20	113	2	15	—	.236
3:25		20	113	2	15	—	.236
3:30		20	113	2	15	—	.236
3:35		20	113	2	15	—	.236
3:45		19.5	112	3	15	—	.212
3:50		19.5	112	3	15	—	.212
3:55		19.5	112	3	15	—	.212
4:00		19.5	112.5	3	15	—	.212

R.P.M.
TS.

ER			RATIOS AND EFFIC'S		
WATTS IMPUT.	NET HORSE POWER APPLIED TO PUMP.	PUMP. H.P.	TOTAL HEAD TO PER VEL HEAD	SUCTION HEAD TO TOTAL HEAD	NET EFFIC'Y OF PUMP
1040	.74	0	64.5	10.0	0
1210	.94	.23	58	13.7	24.5
430	1.2	.64	94	11.7	53.3
710	1.6	.95	86	14.1	59.3
760	1.64	1.15	78.5	17.9	70.3
890	1.81	.98	63.6	23.2	54.1
940	1.86	.68	36.4	45.7	36.5
960	1.88	.80	45.5	68.4	42.5
960	1.88	.995	63	77.3	53.0
900	1.82	1.08	75.9	81	59.6
830	1.72	1.09	89.6	84	63.3
280	2.29	.96	81.1	75.7	41.7
190	2.18	.93	90.6	67.5	42.7

TABLE NO. 10.

COMPLETE TEST AT SPEED OF 850 R.P.M.
CORRECTED DATA AND RESULTS.

DATE	TIME	R.P.M.	VELOCITY IN FEET PER SEC.		CAPACITY					HEADS IN FEET OF WATER					POWER					RATIOS AND EFFIC'S		
					CU. FT. PER SEC.								VEL EQUIVL'T.									
			PERIPHERAL	WATER IN DISCHARGE PIPE	WEIR A	WEIR B	TOTAL	GALLONS PER MIN.	100 POUNDS PER HOUR	SUCTION	DISCHARGE	TOTAL	PERIPHERAL	DISCHARGE PIPE	VOLTS	AMPERES	WATTS INPUT	NET HORSE POWER APPLIED TO PUMP	PUMP. H.P.	TOTAL HEAD TO PER VEL HEAD	SUCTION HEAD TO TOTAL HEAD	NET EFFIC'Y OF PUMP
APRIL 27-09	11:20-11:35	CONSTANT AT 850	CONSTANT AT 41.3	0	0	0	0	0	0	2.3	19.2	23.0	CONSTANT AT 26.4	0	115.4	9	1040	.74	0	64.5	10.0	0
	11:45-12:00			1.85	0	.095	.095	43	215	2.9	16.7	21.1		.053	114.8	10.5	1210	.94	.23	58	13.7	24.5
	12:05-12:20			4.4	0	.228	.228	103	515	2.9	20.4	24.8		.3	114.3	12.5	1430	1.2	.64	94	11.7	53.3
	12:25-12:40			7.15	0	.366	.366	165	825	3.2	18.0	22.7		.79	113.8	15	1710	1.6	.95	86	14.1	59.3
	12:45-1:00			8.4	0	.430	.430	193.5	967.5	3.7	15.5	20.7		1.04	113.8	15.5	1760	1.64	1.15	78.5	17.9	70.3
	1:10-1:25			10.0	0	.513	.513	231	1155	3.9	11.4	16.8		1.56	113.8	16.6	1890	1.81	.98	63.6	23.2	54.1
	1:30-1:45			12.2	0	.628	.628	283	1415	4.4	3.7	9.6		2.32	113.8	17.1	1940	1.86	.68	36.4	45.7	36.5
	1:50-2:05			11.5	0	.591	.591	266	1330	8.2	2.3	12		2.05	114.3	17.1	1960	1.88	.80	45.5	68.4	42.5
	2:10-2:25			10.2	0	.525	.525	236	1180	12.8	2.3	16.6		1.62	114.3	17.1	1960	1.88	.995	63	77.3	53.0
	2:30-2:45			9.2	0	.474	.474	213	1065	16.2	2.3	20.0		1.32	113.8	16.7	1900	1.82	1.08	75.9	81	59.6
	3:00-3:15			7.9	0	.405	.405	182	910	19.9	2.3	23.7		.975	114.2	16	1830	1.72	1.09	89.6	84	63.3
	3:20-3:35			7.7	0	.398	.398	179	895	16.2	3.7	21.4		.92	113.3	20.1	2280	2.29	.96	81.1	75.7	41.7
	3:45-4:00			6.6	0	.340	.340	153	765	16.2	6.3	24.0		.66	112.3	19.5	2190	2.18	.93	90.6	67.5	42.7

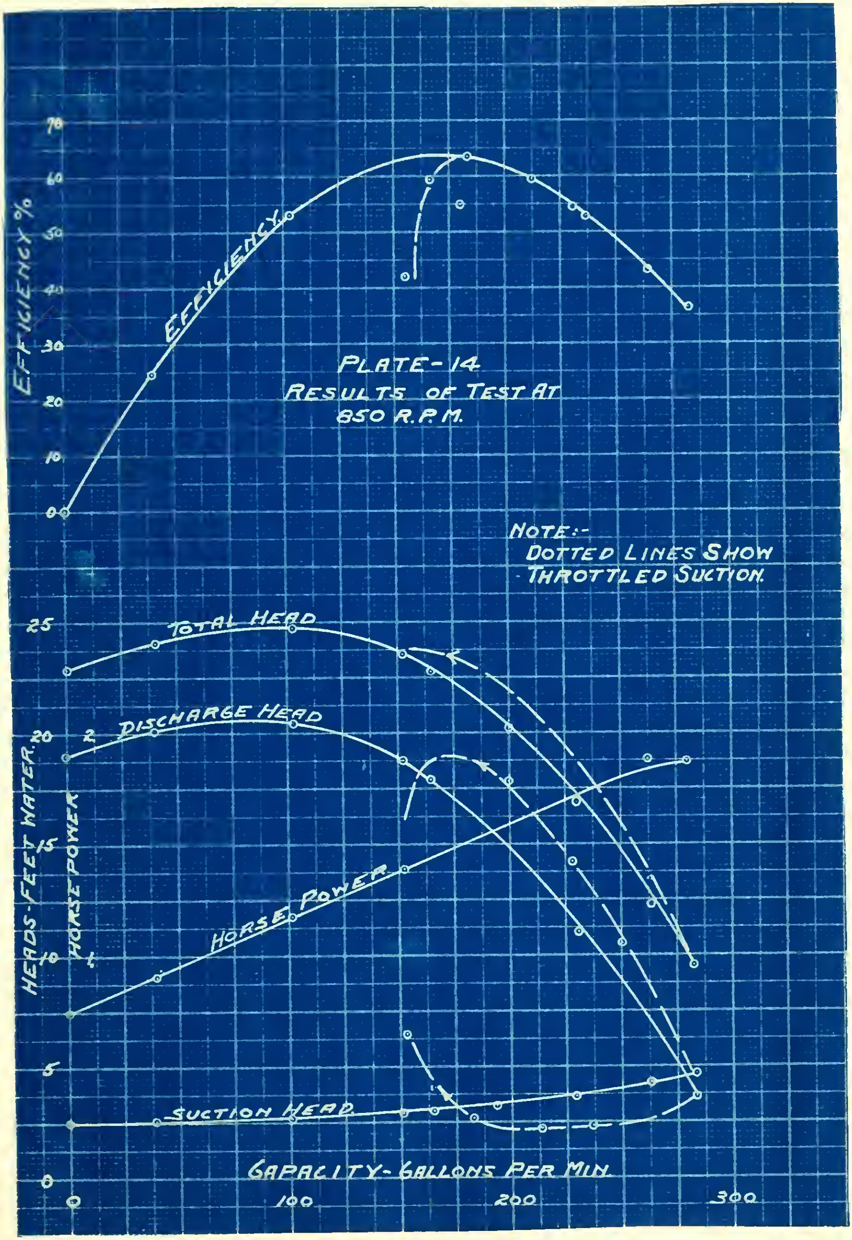

PLATE-14
RESULTS OF TEST AT
850 R.P.M.

NOTE:-
DOTTED LINES SHOW
THROTTLED SUCTION.

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maximum head at 850 R.P.M. is only half that at 1160 R.P.M., while the maximum discharge was reduced from 340 gallons to 285 gallons per minute The first two quantities being in approximate proportion with the squares of the respective velocities; and the second two being near simple ratio with the name, as it should be. The effect of throttling the suction at this speed was to interrupt the operation of the pump at a capacity of 155 gallons per minute. In this test the efficiency curve retraced itself when the suction was throttled.

The data, results, and curves for 1000 r. p. M. are given in table 11 and 12, and plate-1 The effect of throttling the suction at this s speed was similar to that at 1160 R. P. M., both in diminishing the capacity and efficiency of the pump.

In order to run the pump over 1160 R. P. M. the motor was moved down and belted to the pump A test was then made at 1300 R. P. M., the data, results, and curves are given in tables 13, 14,

TABLE No. 11
COMPLETE TEST AT 1000 R.P.M.
RUNNING LOG.

TIME	R.P.M. TACHOMETER	AMPERES	VOLTS	PRESSURE GAUGE	SUCTION HEAD	HEAD ON WEIR A 10"	HEAD ON WEIR B 12"
				#/□"	"HG	FEET.	
APRIL-28-09 9:00	CONSTANT AT 1000 R.P.M.	13	113	14	2.3	—	—
9:05		13	113	14	2.3	—	—
9:10		13	113	14	2.3	—	—
9:15		13	113	14	2.3	—	—
9:20		22	113	14.7	3	—	.200
9:25		22	113	14.8	3	—	.200
9:30		22	113	14.8	3	—	.200
9:35		22	113	14.8	3	—	.200
9:40		26	113	12.6	3.5	—	.259
9:45		25.5	113	12.7	3.5	—	.259
9:50		25.5	113	12.8	3.5	—	.259
9:55		25.5	113	12.7	3.5	—	.259
10:00		27.5	114	10	4.3	—	.298
10:05		27.5	114	10	4.3	—	.298
10:10		27.5	114	10	4.3	—	.298
10:15		27.5	114	10	4.3	—	.298
10:20		27.5	114.5	10	4.2	.068	.279
10:25		27.6	114.5	10	4.2	.068	.279
10:30		27.6	114.5	10	4.2	.068	.279
10:35		27.6	114.5	10	4.2	.068	.279
10:40		29.5	113.0	5	5.2	.208	.256
10:45		30.0	113.0	5	5.2	.208	.256
10:50		30.0	113.0	5	5.2	.208	.256
10:55		30.0	113.0	5	5.2	.208	.256
11:00		30	112.0	1.5	5.5	.214	.260
11:05		30	112.5	1.5	5.5	.214	.260
11:10		30	112.5	1.5	5.5	.214	.260
11:15		30	112.5	1.5	5.5	.214	.260

TABLE No. 11
COMPLETE TEST AT 1000 R.P.M.
RUNNING LOG. CONT.

TIME	R.P.M. TACHOMETER	AMPERES	VOLTS	PRESSURE GAUGE #/□"	SUCTION HEAD "HG	HEAD ON WEIR A 10" FEET	HEAD ON WEIR B 12" FEET
11:20	CONSTANT AT 1000 R.P.M.	29	110.5	1.4	8	.214	.260
11:25		29	110.5	1.4	8	.214	.260
11:30		30	110.5	1.4	8	.214	.260
11:35		29.5	110.5	1.4	8	.214	.260
11:40		29	110.5	1.2	11	.184	.252
11:45		29	110.5	1.2	11	.184	.252
11:50		29	110.5	1.2	11	.184	.252
11:55		29.5	110.5	1.2	11	.184	.252
12:00		28	110.5	1.1	14	—	.313
12:05		28	110.5	1.1	14	—	.313
12:10		28	111.0	1.1	14	—	.313
12:15		28	111.0	1.1	14	—	.313
12:20		30.5	111	1.1	20	—	.250
12:25		30.5	111	1.1	20	—	.250
12:30		30.0	111	1.1	20.5	—	.250
12:35		30.0	111	1.1	20.5	—	.250
12:40		27	110.5	1.1	17	—	.293
12:45		27	110.5	1.1	17	—	.293
12:50		27	111	1.1	17	—	.293
12:55		27	111	1.1	17	—	.293
1:00		27	113.5	6.6	17	—	.271
1:05		27	113.5	6.6	17	—	.271
1:10		27	113.5	6.6	17	—	.271
1:15		27	113.5	6.6	17	—	.271
1:20		25.5	114	8.	17	—	.243
1:25		25.5	114	8.	17	—	.243
1:30		25.0	114	8.	17	—	.243
1:35		25.0	114	8.	17	—	.243

				RATIOS AND EFFICY		
DATE	TIM	APPLIED TO PUMP	PUMP H.P.	TOTAL HEAD TO PER VEL. HEAD	SUCTION HEAD TO TOTAL HEAD	NET EFFIC'Y OF PUMP.
APRIL-28-09	9:00-	25	0	104.5	5.5	0
	9:20-	.51	1.44	111.5	7.15	57.5
	9:40-	94	1.84	98	9.55	62.6
	10:00-	25	1.93	83	13.9	59.5
	10:20-	09	1.91	82.7	13.6	61.8
	10:40	56	1.43	49.5	28.3	40.3
	1100-	.90	.77	25.6	59.2	19.7
	11:20-	34	.94	33	68.4	28.2
	11:40	30	1.13	42	75.2	34.2
	12:00-	22	1.36	52.2	80	42.3
	12:20-	10	1.47	64.6	84	47.5
	12:40	34	1.3	72.5	85.5	39.0
	1:00-	.15	1.98	98.5	51.9	63.3
	1:20-	69	1.80	105	48.6	62.3

TABLE NO. 12

COMPLETE TEST AT 1000 R.P.M.

CORRECTED DATA AND RESULTS

			VELOCITY IN FEET PER SEC.		CAPACITY					HEADS IN FEET OF WATER					POWER					RATIOS AND EFFICY		
					CU. FT. PER SEC.								VEL. EQUIVL'T.									
DATE	TIME	R.P.M.	PERIPHERAL	WATER IN DISCHARGE PIPE	WEIR A	WEIR B	TOTAL	GALLONS PER MIN.	100 POUNDS PER HOUR	SUCTION	DISCHARGE	TOTAL	PERIPHERAL	DISCHARGE PIPE	VOLTS	AMPERES	WATTS IMPUT	NET HORSE POWER APPLIED TO PUMP	PUMP H.P.	TOTAL HEAD TO PER VEL. HEAD	SUCTION HEAD TO TOTAL HEAD	NET EFFIC'Y OF PUMP
APRIL-29-09	9:00-9:15	CONSTANT AT 1000	CONSTANT AT 48.6	0	0	0	0	0	0	2.1	34.4	38	CONSTANT AT 36.4	0	113.3	13	1470	1.25	0	104.5	5.5	0
	9:20-9:35			6.1	0	.313	.313	141	705	2.9	36.2	40.6		.580	113.3	22.1	2510	2.51	1.44	111.5	7.15	57.5
	9:40-9:55			8.8	0	.456	.456	205	1025	3.4	30.7	35.6		1.21	113.3	25.6	2890	2.94	1.84	98	9.55	62.6
	10:00-10:15			10.9	0	.562	.562	253	1265	4.2	24.5	30.2		1.86	114.3	27.8	3180	3.25	1.93	83	13.9	59.5
	10:20-10:35			10.8	.050	.508	.558	251	1255	4.1	24.5	30.1		1.83	114.8	27.4	3020	3.09	1.91	82.7	13.6	61.8
	10:40-10:55			13.2	.254	.448	.702	320	1600	5.1	11.4	18		2.72	113.3	30.3	3430	3.56	1.43	49.5	28.3	40.3
	11:00-11:15			14.1	.264	.458	.722	326	1630	5.5	2.3	9.3		3.12	112.7	34	3830	3.90	.77	25.6	59.2	19.7
	11:20-11:35			13.5	.246	.445	.691	311	1555	8.2	2.3	12		2.86	110.7	30	3320	3.34	.94	33	68.4	28.2
	11:40-11:55			12.6	.215	.434	.649	292	1460	11.5	2.3	15.3		2.49	110.7	29.4	3250	3.30	1.13	42	75.2	34.2
	12:00-12:15			11.8	0	.605	.605	272	1360	15.2	2.3	19		2.17	110.9	28.4	3150	3.22	1.36	52.2	80	42.3
	12:20-12:35			10.7	0	.548	.548	247	1235	19.7	2.3	23.5		1.80	110.9	27.3	3030	3.10	1.47	64.6	84	47.5
	12:40-12:55			8.4	0	.434	.434	195	975	22.6	2.3	26.4		1.1	111.2	30.6	3400	3.34	1.3	72.5	85.5	39.0
	1:00-1:15			9.4	0	.486	.486	219	1095	18.6	15.8	34.9		1.38	113.8	27.3	3100	3.15	1.98	98.5	51.9	63.3
	1:20-1:35			8.1	0	.414	.414	186	930	18.6	19.2	38.3		1.02	114.3	24.8	2850	2.89	1.80	105	48.6	62.3

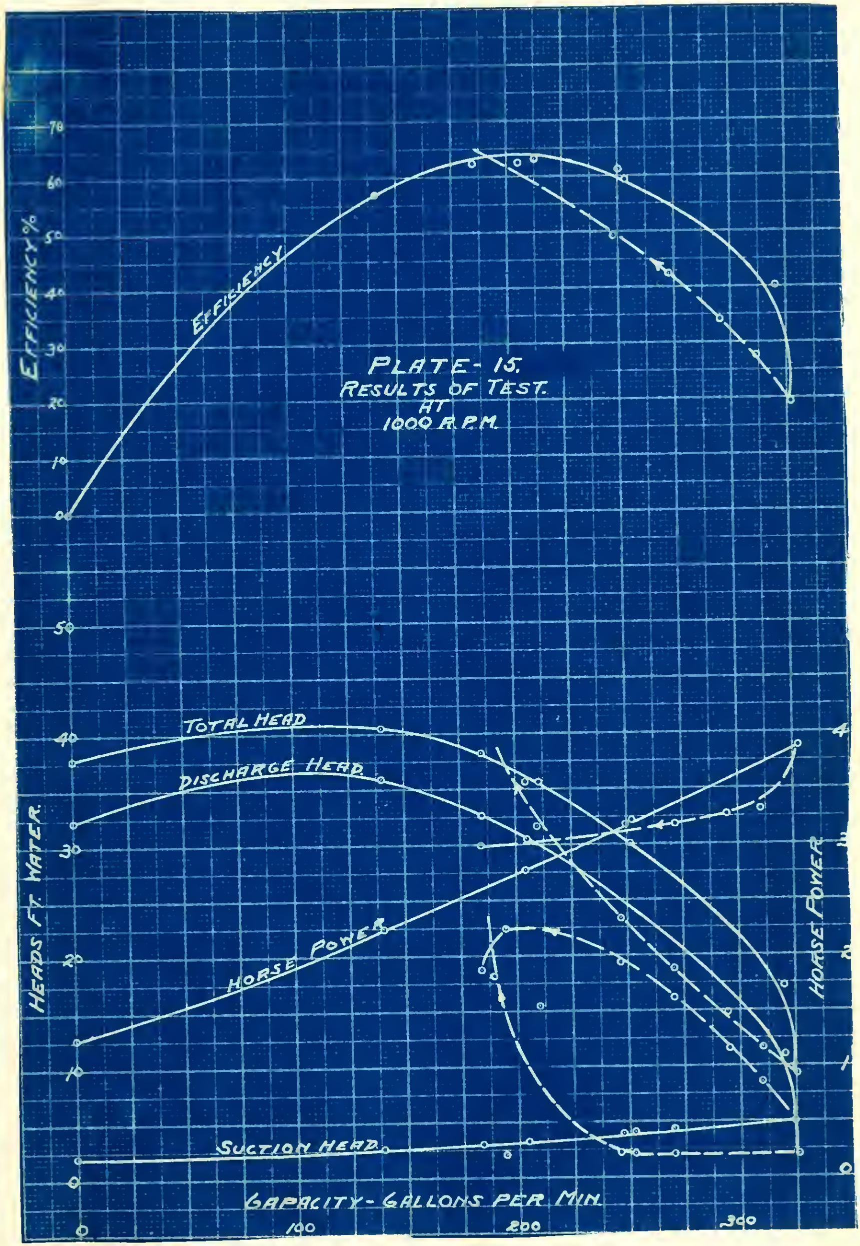

PLATE - 15.
RESULTS OF TEST
AT
1000 R.P.M.

and 15, and plate 16. The increase in speed greatly increased the range of operation of the pump, and gave an efficiency higher than in any other case. The effect of throttling the suction at this speed is more marked than in any previous run, in that the efficiency is lowered throughout the entire range.

Tables 16, 17 and 18, and plate 17 give the results and curves for the test at 1450 R. P. M. At this speed the pump has a maximum efficiency equal to that of 1160 R. P. M., but for only a very short range of capacity. The total head is almost twice as great as at the other speeds and the effect of throttling the suction is the same as the previous test of 1300 R. P. M.

Plate 18 shows a comparison of the operation of the pump at different speeds. The curve indicate the variation of efficiency with the speed, at various capacities from fifty to three hundred gallons per minute. These curves show the great advantage of regulating the capacity of the pump by changing the speed of the impeller

TABLE No. 13
FIFTH TEST FOR CHARACTERISTIC OF IMPELLER
RUNNING LOG

TIME	R.P.M. TACHOMETER	AMPERES	VOLTS	PRESSURE GAUGE	SUCTION HEAD	HEAD ON WEIR A 10"	HEAD ON WEIR B 12"
				#/□"	"HG	FEET	
MAY-6-09							
9:50	1300	24	111	26	2		
9:55	1300	24.5	111	26	2		
10:00	1300	24.5	111	26	2		
10:05	1300	25	111	26	2		
10:10	1300	38	110	26	3		.202
10:15	1300	37.5	110	26	3		.202
10:20	1300	37.5	110	26	3		.202
10:25	1300	37.	110	26	3		.202
10:30	1300	47.5	111	21.8	4		.289
10:35	1300	47.5	111	21.8	4		.289
10:40	1300	47.5	111	21.8	4		.289
10:45	1300	47.5	111	21.8	4		.289
10:50	1280	51.5	110	17.5	5	.163	.272
10:55	1280	51.5	110	17.5	5	.163	.272
11:00	1280	51.0	110	17.5	5	.163	.272
11:05	1280	52.0	110	17.5	5	.163	.272
11:10	1300	54	110	13	5.4	.215	.263
11:15	1300	54	110	13	5.4	.215	.265
11:20	1300	54	110	13	5.4	.215	.265
11:25	1300	54	110	13	5.4	.215	.265
11:30	1280	52.5	111.	7	5.7	.228	.269
11:35	1280	52.0	110.5	7	5.7	.228	.269
11:40	1280	52.5	110.5	7	5.7	.228	.269
11:45	1280	53.0	110.	7	5.7	.228	.269
11:50	1280	53.5	110	2	6.2	.247	.277
11:55	1280	54.0	110	2	6.2	.247	.277
12:00	1280	54.0	110	2	6.2	.247	.277
12:05	1280	55.0	110	2	6.2	.247	.277

TABLE No. 14
TEST FOR EFFECT OF THROTTLING SUCTION
RUNNING LOG.

TIME	R.P.M. TACHOMETER	AMPERES	VOLTS	PRESSURE GAUGE #/□"	SUCTION HEAD "HG	HEAD ON WEIR A 10" FEET	HEAD ON WEIR B 12" FEET
MAY 6-09							
12:20	1280	51	110	1.9	10	.230	.271
12:25	1280	51	110	1.9	10	.230	.271
12:30	1280	51	110	1.9	10	.230	.271
12:35	1280	51	110	1.9	10	.230	.271
12:40	1280	48.5	109	1.5	15	.204	.262
12:45	1280	49	109	1.5	15	.204	.262
12:50	1280	48.5	110	1.5	15	.204	.262
12:55	1280	48.0	110	1.5	15	.204	.262
1:00	1300	43.5	110	1.5	20	—	.314
1:05	1300	43.0	110	1.5	20	—	.314
1:10	1300	43.0	110	1.5	20	—	.314
1:15	1300	43.5	110	1.5	20	—	.314
1:20	1300	37.5	110	1.1	22	—	.274
1:25	1300	37.5	110	1.1	22	—	.274
1:30	1300	37.	110	1.1	22	—	.274
1:35	1300	37.	110	1.1	22	—	.274
1:40	1300	42.5	111	10	22	—	.259
1:45	1300	42.5	111	10	22	—	.259
1:50	1300	42.5	111	10	22	—	.259
1:55	1300	42.5	111	10	22	—	.259
2:00	1300	39.5	111	14	22	—	.211
2:05	1300	39.5	111	14	22	—	.211
2:10	1300	39.5	111	14	22	—	.211
2:15	1300	39.5	111	14	22	—	.211

			RATIOS AND EFFICIENCY			
IMPUT	NET HORSE POWER APPLIED TO PUMP.	PUMP H.P.	TOTAL HEAD TO PER. VEL. HEAD	SUCTION HEAD TO TOTAL HEAD	REJECTED HEAD TO TOTAL HEAD	NET EFFIC'Y OF PUMP.
30	2.75	0	104.5	2.7	0	0
30	4.24	2.35	108	4.45	.92	55.5
80	5.39	3.52	94.5	6.8	2.96	65.4
30	5.86	3.[illegible]6	79.7	10.2	5.6	62.5
00	6.10	3.24	64	13.5	8.4	53.2
70	5.98	2.10	39.6	24.3	14.9	35.1
70	6.08	1.09	19.1	54.7	35.6	17.9
0	5.78	1.35	25.5	67.5	23.2	23.4
70	5.51	1.63	33.6	80.6	14.6	29.6
30	4.96	1.82	43.5	85.0	8.5	36.7
90	4.05	1.62	47.6	87.0	5.1	40.0
90	5.10	2.61	84.2	49.4	3.2	51.2
60	4.55	2.19	105	41.3	1.1	48.2

TABLE NO. 15

COMPLETE TEST AT 1300 R.P.M.

CORRECTED DATA AND RESULTS.

DATE	TIME	R.P.M.	VELOCITY IN FEET PER SEC.		CAPACITY					HEADS IN FEET OF WATER					POWER					RATIOS AND EFFICIENCY			
					CU. FT. PER SEC.								VEL. EQUIVL'T.										
			PERIPHERAL	WATER IN DISCHARGE PIPE	WEIR A	WEIR B	TOTAL	GALLONS PER MIN.	100 POUNDS PER HOUR	SUCTION	DISCHARGE	TOTAL	PERIPHERAL	DISCHARGE PIPE	VOLTS	AMPERES	WATTS INPUT	NET HORSE POWER APPLIED TO PUMP	PUMP H.P.	TOTAL HEAD TO PER. VEL. HEAD	SUCTION HEAD TO TOTAL HEAD	REJECTED HEAD TO TOTAL HEAD	NET EFFIC'Y OF PUMP
MAY-6-09	9:50-10:05	CONSTANT AT 1300	CONSTANT AT 63.2	0	0	0	0	0	0	1.7	60	63.2	CONSTANT AT 60.4	0	111.2	24.5	2730	2.75	0	104.5	2.7	0	0
	10:10-10:25			6.2	0	.318	.318	143	715	2.9	61.8	65.2		.6	110.2	38.	4180	4.24	2.35	108	4.45	.92	55.5
	10:30-10:45			10.4	0	.536	.536	241	1205	3.9	52.7	57.1		1.69	111.2	48	5280	5.39	3.52	94.5	6.8	2.96	65.4
	10:50-11:05			13.1	.182	.490	.672	352	1510	4.9	42.7	48.1		2.69	110.2	52	5730	5.86	3.66	79.7	10.2	5.6	62.5
	11:10-11:25			14.4	.266	.472	.738	332	1660	5.2	31.9	38.6		3.25	110.2	54.4	6000	6.10	3.24	64	13.5	8.4	53.2
	11:30-11:45			15.1	.289	.482	.771	347	1735	5.8	16.6	23.9		3.56	110.7	53	5870	5.98	2.10	39.6	24.3	14.9	35.1
	11:50-12:05			16.2	.325	.503	.828	373	1865	6.3	3.7	11.5		4.1	110.2	54.2	5970	6.08	1.09	19.1	54.7	35.6	17.9
	12:20-12:35			15.2	.293	.487	.780	351	1755	10.4	3.5	15.4		3.6	110.2	51.4	5660	5.78	1.35	25.5	67.5	23.2	23.4
	12:40-12:55			13.8	.247	.463	.710	320	1600	16.3	2.5	20.3		2.97	109.7	49	5370	5.51	1.63	33.6	80.6	14.6	29.6
	1:00-1:15			11.9	0	.608	.608	270	1350	22.3	2.5	26.3		2.22	110.2	43.8	4830	4.96	1.82	43.5	85.0	8.5	36.7
	1:20-1:35			9.7	0	.495	.495	223	1115	25.0	2.3	28.8		1.47	110.2	37.8	3990	4.05	1.62	47.6	87.0	5.1	40.0
	1:40-1.55			10.25	0	.456	.456	261	1305	25.0	24.3	50.8		1.64	111.2	43.0	4890	5.10	2.61	84.2	49.4	3.2	51.2
	2:00-2:15			6.6	0	.338	.338	152	760	25.0	34.2	60.7		.68	111.2	40.1	4460	4.55	2.19	105	41.3	1.1	48.2

TABLE No. 16

FOURTH TEST FOR CHARACTERISTIC OF IMPELLER RUNNING LOG.

TIME	R.P.M. TACHOMETER	AMPERES	VOLTS	PRESSURE GAUGE	SUCTION HEAD	HEAD ON WEIR A 10"	HEAD ON WEIR B 12"
				#/□"	"HG	FEET	
MAY·4·09							
9:00	1500	41	108.5	35	3.5	—	—
9:05	1480	41	108.5	35	3.5	—	—
9:10	1490	41	108.5	35	3.5	—	—
9:15	1500	41	108.5	35	3.5	—	—
9:20	1500	59	108.5	38	3.9	—	.149
9:25	1480	59	108.5	38	3.9	—	.149
9:30	1490	60	108.5	38	3.9	—	.149
9:35	4490	60	108.5	38	3.9	—	.149
9:40	1480	73	108	38	3.9	—	.215
9:45	1480	67	107	40	3.9	—	.215
9:50	1500	71	107	39	3.9	—	.215
9:55	1510	71	107	39	3.9	—	.215
10:00	1450	85	107.5	34	4.4	—	.277
10:05	1445	79	107.5	34.5	4.3	—	.277
10:10	1455	82	107.5	35	4.3	—	.277
10:15	1450	83	107.5	34.5	4.2	—	.277
10:20	1455	86	107	30	4.5	.181	.224
10:25	1440	86	107	30	4.5	.181	.224
10:30	1455	86.5	107	31	4.5	.181	.224
10:35	1450	86.5	107	31	4.5	.181	.224

TABLE NO. 16
FOURTH TEST FOR CHARACTERISTIC OF IMPELLER
RUNNING LOG CONT.

TIME	R.P.M. TACHOMETER	AMPERES	VOLTS	PRESSURE GAUGE	SUCTION HEAD	HEAD ON WEIR A 10"	HEAD ON WEIR B 12"
				#/□"	"HG	FEET	
MAY-4-09							
10:40	1450	90.0	107	2.5	5.5	.229	.237
10:45	1450	90.0	107	2.5	5.5	.229	.237
10:50	1440	90.0	107	2.5	5.5	.229	.237
10:55	1445	900	107	2.5	5.5	.229	.237
11:00	1430	86	107.5	10.2	6	.255	.246
11:05	1425	87	108.0	10.2	6	.255	.246
11:10	1420	88	108.0	10.2	6	.255	.246
11:15	1425	87	107.0	10.2	6	.255	.246
11:20	1450	85	107	2.5	7	.288	.257
11:25	1450	84	107	2.5	7	.288	.257
11:30	1450	84.5	107	2.5	7	.288	.257
11:40	1450	84.5	107	2.5	7	.288	.257

TABLE No. 17
TEST FOR EFFECT OF THROTTLING SUCTION
RUNNING LOG

TIME	R.P.M. TACHOMETER	AMPERES	VOLTS	PRESSURE GAUGE	SUCTION HEAD	HEAD ON WEIR A 10"	HEAD ON WEIR B 12"
				#/□"	"HG	FEET	
MAY-4-09							
12:00	1450	84	107	22	10	.275	.254
12:05	1450	83	106	2.2	10	.275	.254
12:10	1450	83	108	2.3	10	.275	.254
12:15	1450	82	107	22	10	.275	.254
12:20	1445	80	106	2.1	13	.262	.248
12:25	1440	80.5	106	2.1	13	262	.248
12:30	1445	80.5	107	2.1	13	.262	.248
12:35	1450	81	107	2.1	13	.262	.248
12:40	1450	79	106.5	2	17	.244	.242
12:45	1460	78	106.5	2	17	244	.242
12:50	1465	79	107.0	2	17	.244	.242
12:55	1465	78	107.0	2	17	.244	242
1:00	1500	72	108	1.3	23	.195	.227
1:05	1510	72	108	1.3	23	.195	.227
1:10	1505	72	108.5	1.3	23	.195	.227
1:15	1505	72	108.5	1.3	23	.195	.227
1:20	1540	62	112	1.2	24.7	—	.256
1:25	1540	62	112	1.2	24.7	—	.256
1:30	1540	62	112	1.2	24.7	—	.256
1:35	1540	62	112	1.2	24.7	—	.256

TABLE NO. 17
TEST FOR EFFECT OF THROTTLING SUCTION
RUNNING LOG CONT.

TIME	R.P.M. TACHOMETER	AMPERES	VOLTS	PRESSURE GAUGE	SUCTION HEAD	HEAD ON WEIR A 10"	HEAD ON WEIR B 12"
				#/□"	"HG	FEET.	
MAY-4-09							
1:50	1500	68	111	5	22	.182	.220
1:55	1500	68	111	5	22	.182	.220
2:00	1500	68	111	5	22	.182	.220
2:05	1500	68	111	5	22	.182	.220
2:10	1500	69	111	12	22	—	.283
2:15	1500	69	110.5	12	22	—	.283
2:20	1500	69	110.5	12	22	—	.283
2:25	1500	69	110.5	12	22	—	.283
2:30	1490	73	110	20	22	—	.260
2:35	1495	73	110.5	20	22	—	.260
2:40	1495	73	110.5	20	22	—	.260
2:45	1500	73	111.0	20	22	—	.260
2:50	1500	69	111	24	22	—	.228
2:55	1510	69	111	24	22	—	.228
3:00	1520	69	111	24	22	—	.228
3:05	1510	69	111	24	22	—	.228

		RATIOS AND EFFICIENCIES			
NET HORSE POWER APPLIED TO PUMP	PUMP H.P.	TOTAL HEAD TO PER VEL HEAD	SUCTION HEAD TO TOTAL HEAD	REJECTED HEAD TO TOTAL HEAD	NET EFFIC'Y OF PUMP
4.53	0	123	4.6	0	0
6.47	2.08	127	4.24	.28	32.2
7.40	3.64	130	4.13	.78	49.2
8.20	4.90	121	4.9	1.75	59.8
8.63	5.05	109	5.86	2.56	56.5
9.00	5.24	95	8.25	4.28	58.2
8.85	2.93	46.4	18.7	10.6	33.1
8.55	1.33	19.3	51.5	32.1	15.6
8.42	1.52	23.3	63.5	24.7	18.1
8.25	1.73	27.5	71.6	18.9	21.0
8.05	1.98	33.8	78.2	13.4	24.6
7.59	2.07	42.	87.3	7.36	27.3
6.84	1.63	45.1	88.0	3.7	23.8
7.53	2.95	54	65.6	5.06	39.2
7.45	3.3	79.6	44.5	2.84	44.4
7.82	3.96	106	33.3	1.65	50.5
7.47	4.07	135	26.2	.9	54.5

TABLE NO. 18

COMPLETE TEST AT 1450 R.P.M.

CORRECTED DATA AND RESULTS

DATE	TIME	R.P.M.	VELOCITY IN FEET PER SEC.		CAPACITY					HEADS IN FEET OF WATER					POWER					RATIOS AND EFFICIENCIES			
					CU. FT. PER SEC.								VEL. EQUIV'L'T										
			PERIPHERAL	WATER IN DISCHARGE PIPE	WEIR A	WEIR B.	TOTAL	GALLONS PER MIN.	100 POUNDS PER HOUR	SUCTION	DISCHARGE	TOTAL	PERIPHERAL	DISCHARGE PIPE	VOLTS	AMPERES	WATTS INPUT	NET H.P. [illegible] POWER APPLIED TO PUMP	PUMP H.P.	TOTAL HEAD TO PER VEL HEAD	SUCTION HEAD TO TOTAL HEAD	REJECTED HEAD TO TOTAL HEAD	NET EFFIC'Y OF PUMP.
MAY 4-09	9:00-9:15	CONSTANT AT 1450	CONSTANT AT 77.2	0	0	0	0	0	0	4	81.6	87.1	CONSTANT AT 70.5	0	108.7	41.5	4500	4.53	0	123	4.6	0	0
	9:20-9:35			4.	0	.204	.204	92	460	3.8	84.4	89.7		.25	108.7	60.	6520	6.47	2.08	127	4.24	.28	32.2
	9:40-9:55			6.8	0	.348	.348	157	785	3.8	86.7	92.0		.72	107.3	71	7630	7.40	3.64	130	4.13	.78	49.2
	10:00-10:15			9.8	0	.504	.504	227	1135	4.2	80.0	85.7		1.50	107.7	82.3	8650	8.20	4.90	121	4.9	1.75	59.8
	10:20-10:35			11.2	.210	.368	.578	260	1300	4.5	70.8	76.8		1.96	107.2	86.8	9200	8.63	5.05	109	5.86	2.56	58.5
	10:40-10:55			13.5	.292	.400	.692	311	1555	5.5	59.8	66.8		2.86	107.2	90.4	9680	9.00	5.24	95	8.25	4.28	58.2
	11:00-11:15			14.9	.341	.423	.764	344	1720	6.1	25.0	32.6		3.46	107.8	87.4	9440	8.85	2.93	46.4	18.7	10.6	33.1
	11:20-11:35			16.7	.408	.450	.858	386	1930	7.0	5.1	13.6		4.37	107.2	84.9	9100	8.55	1.33	19.3	51.5	32.1	15.6
	12:00-12:15			16.1	.381	.443	.824	371	1855	10.4	4.5	16.4		4.05	106.7	83.4	8900	8.42	1.52	23.3	63.5	24.7	18.1
	12:20-12:35			15.3	.354	.428	.782	352	1760	13.9	4.0	19.4		3.66	106.7	80.9	8650	8.25	1.73	27.5	71.6	18.9	21.0
	12:40-12:55			14.3	.319	.413	.732	329	1645	18.6	3.7	23.8		3.20	106.9	78.9	8450	8.05	1.98	33.8	78.2	13.4	24.6
	1:00-1:15			11.8	.233	.376	.609	274	1370	25.8	2.3	29.6		2.18	108.5	72.4	7850	7.59	2.07	42.	87.3	7.36	27.3
	1:20-1:35			8.7	0	.448	.448	202	1010	28.0	2.3	31.8		1.18	112.2	62.4	7000	6.84	1.63	45.1	88.0	3.7	23.8
	1:50-2:05			11.1	.212	.360	.572	257	1285	25.0	11.6	38.1		1.93	111.3	68.4	7720	7.53	2.95	54	65.6	5.06	39.2
	2:10-2:25			10.1	0	.520	.520	234	1170	25.0	29.6	56.1		1.59	110.8	69.4	7700	7.45	3.3	79.6	44.5	2.84	44.4
	2:30-2:45			8.9	0	.458	.458	206	1030	25.0	48.5	75.0		1.24	110.8	73.4	8140	7.82	3.96	106	33.3	1.65	50.5
	2:50-3:05			7.4	0	.378	.378	170	850	25.0	69.0	95.5		.86	111.2	69.4	7720	7.47	4.07	135	26.2	.9	54.5

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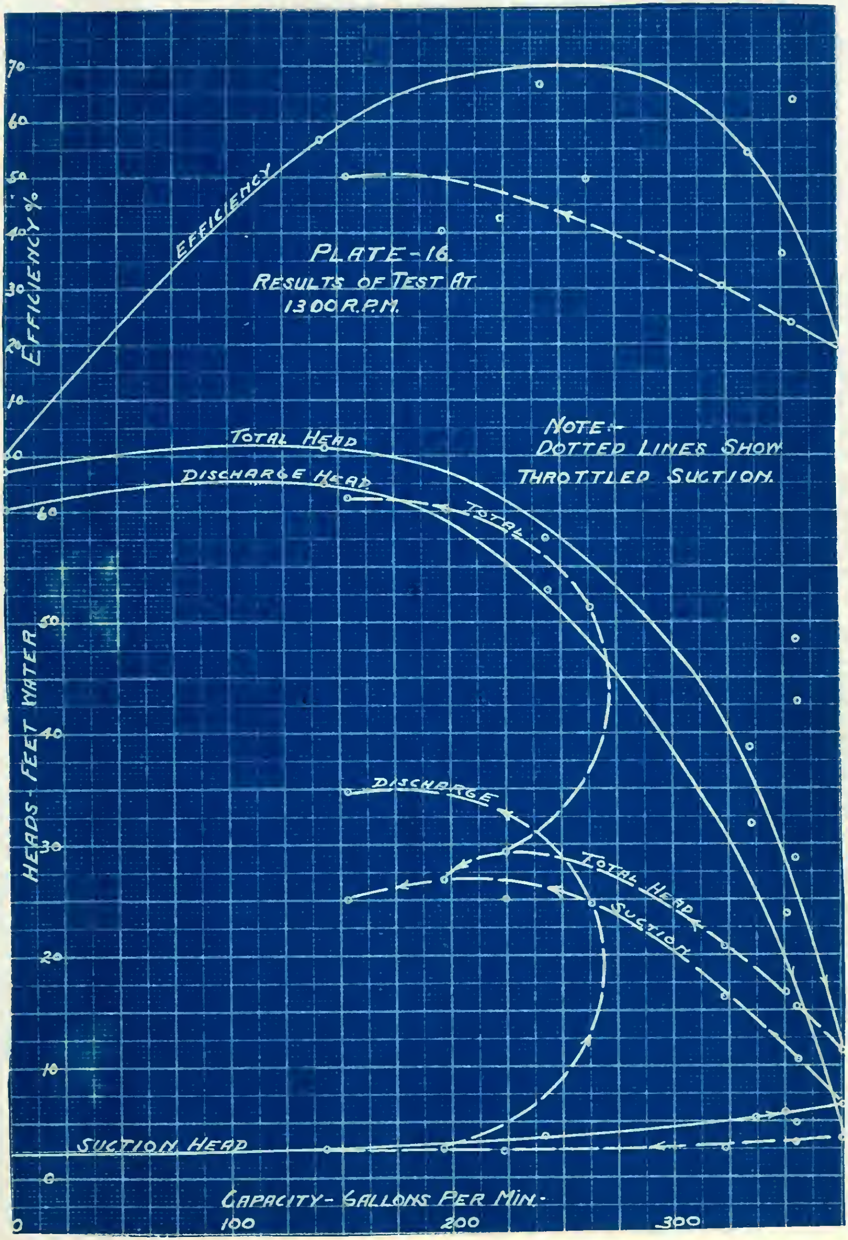


PLATE-16.
RESULTS OF TEST AT 1300 R.P.M.

NOTE - DOTTED LINES SHOW THROTTLED SUCTION.

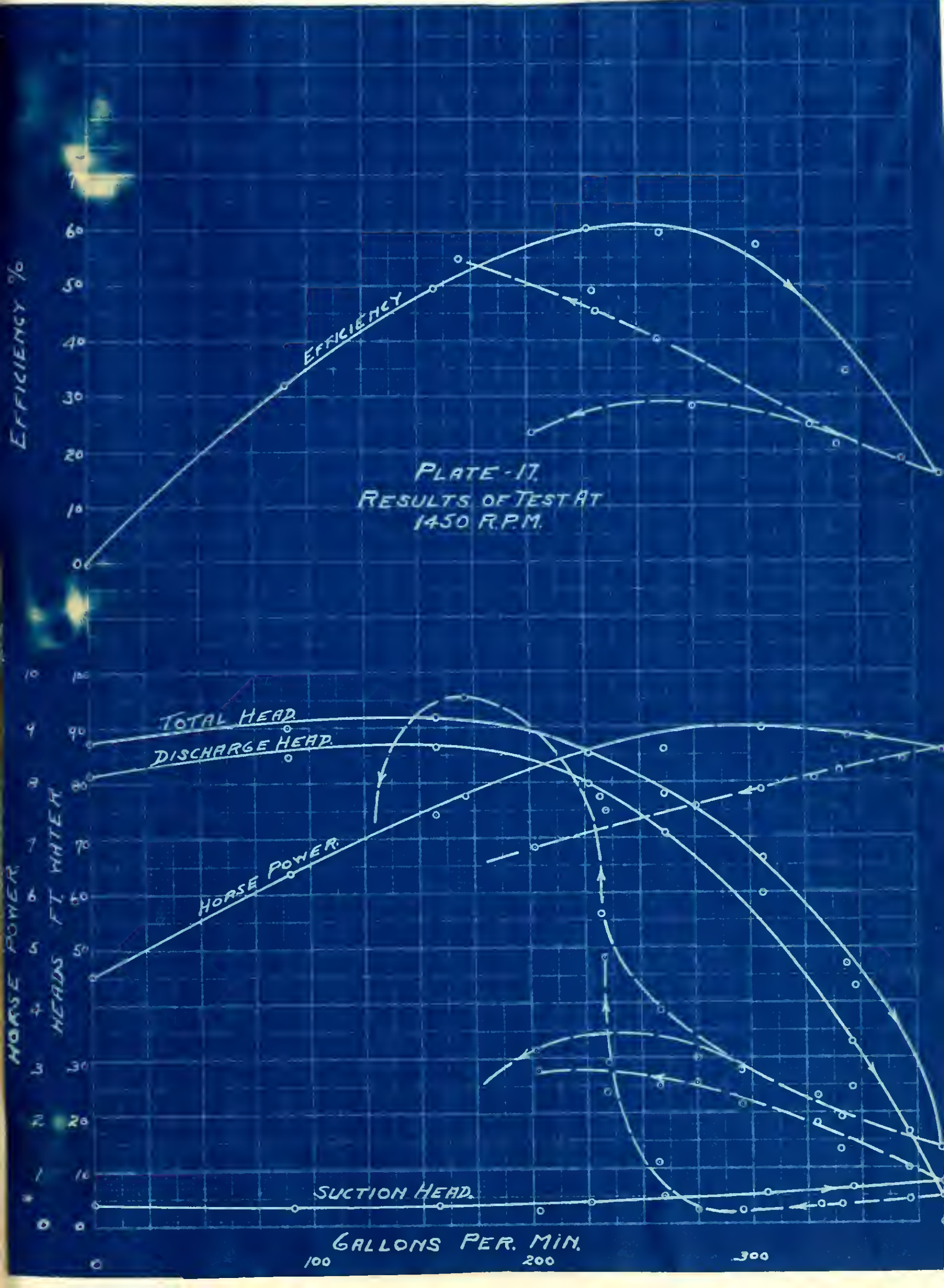


Plate - 17.
Results of Test At
1450 R.P.M.

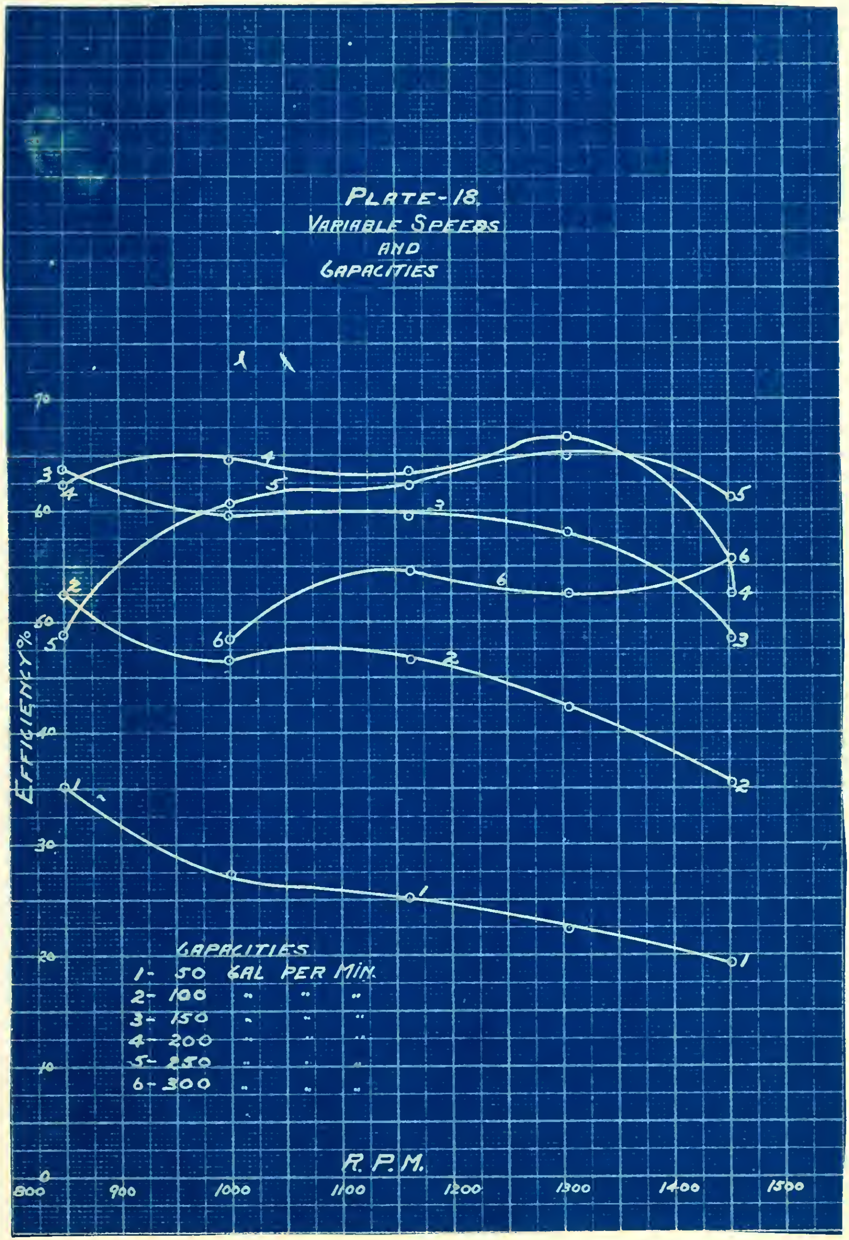


PLATE-18.
VARIABLE SPEEDS
AND
CAPACITIES

Discussion:..

In dealing with the effect of throttling the suction of a centrifugal pump, in comparison with throttling the discharge, the theoretical consideration of the subject has to be left out entirely, since theoretically suction and discharge have the same effect for equal magnitudes the operation of the pump depending entirely upon the speed of the impeller. Following the series of tests in this work it will be seen that while the operation of the pump in general does depend upon the speed of the impeller, the quantity of discharge, however depends upon the valve openings. The total head for a given speed depends mainly upon the quantity of discharge.

The conclusions to be made in regard to th main object of the work, according to the pleases outlined in the introduction are as follows.

First:- If the speed of the pump can not be reduced it is more efficient to cut down the capacity by throttling the discharge than by throttling the suction. If however the suction to reduce the capacity of the pump.

Second:- It is certainly more efficient to place the pump as near the level of the inlet water as possible and to avoid the effect of suction.

In regard to the third place, or effect of self-throttling by the foot valve. The conclusions to be made is characterised by Prof. Anderson, in an expression, "That even in such a simple devise as a foot valve there is much room for improvement."

Method of Caluculating Results.

The results of the given tests were calculated by means of a set of curves specially designed for this purpose. Following is a copy of the curves and a sample calculations quoted from an article entitled "Curves For Engineering Calculation" written by J. M. Spitzglass. The construction of these and similar curves, and the method of their combination is fully explained in the same article.

"A three inch centrifugal pump was operated belt driven by a 10 H. P. motor the respective pulleys on the motor and pump being 20 inches and 10 inches respectively. The impeller has a diameter of 11 1/8 inch, the suction pipe 4 inches standard, the discharge pipe 3 inches. The water delivered was measured by passing through two weir notches, in parallel, one 10 inches marked A, the other 12 inches marked B. The suction head was indicated by a mercury manometer reading in inches, and delivery head by a pressure gauge in pounds per square inch. The power

input to the motor was measured by an ammeter and voltmeter connected to the terminals of the machine.

"Date given for this run:

1. Ammeter reading............ 55. amps.
2. Voltmeter "................ 111. Volts.
3. Motor Speed................ 650. R. P. M.
4. Pump Shaft speed...........1250. " "
5. Discharge gauge............ 14.5 pounds sq. in.
6. Suction gauge.............. 8.5 inches of mercury.
7. Distance between gauge..... 1.5 foot.
8. Head on Weir A.............254 thousandths.
9. " " " B.............232 "

Results required for complete analysis:

Capacity:

1. Cubic feet per second on weir A
2. " " " " " " B
3. Total quantity in cubic feet per second.
4. " " " Gallons per minute.
5. " " " 100 pounds per hour.
6. Velocity of water in inlet pipe.
7. " " " " Discharge pipe.

8. Peripheral velocity of impeller.

Heads in feet of water.

1. Suction head....................feet.
2. Delivery " .... "
3. Total head .... "
4. Inlet velocity equivalent head. "
5. Discharge " " " "
6. Peripheral " " " "

Power:

1. Watts consumed from line. (input)
2 2. Horse power delivered by motor. (output)
3. Percent left after belt slip.
4. Net motive horse power.
5. Pump horse power.
6. Power rejected in discharge velocity.

Ratios and efficiency:

1. Ratio of total head to peripheral velocity head %
2. Ratio of suction head to total head %
3. " " Rejected " " " " %
4. Net efficiency of pump %

These results follow along the dotted lines

on the diagram, the number in order, as given below corresponding to each result is encircled near the point on the respective curve.

#1. Cubic feet per second on weir A is given directly on its curve (section A) by the abscissa corresponding to the head of 254, and reads 0.347 Cubic feet.

#2. Same on weir B is given on its curve by the abscissa corresponding to the head of 232, and reads 0.391.

#3. Total discharge in cubic feet per second is the sum of these two abscissa, a, and b, and reads 0.728 cubic feet.

(The reason for scaling instead of simple addition is to have the sum at once located on the diagram).

#4, and #5. Gallons per minute and 100 pounds per hour are given directly under the quantity on their respective scales, and read 332.1 and 1660.5 respectively.

#6. Velocity of water in inlet pipe is given by the ordinate of its curve corresponding to the abscissa of the total quantity, and reads 8.4 feet per second.

#7. Velocity of water in discharge pipe is given by the ordinate of its curve at the same abscissa, and reads 14.4 feet per second.

#8. Suction head in feet of water is given by the ordinate corresponding to 8.5 inches of mercury on the respective curve in section B, and reads 9.6 feet of water.

#9. Delivery head in feet of water is given by the ordinate corresponding to 14.5 pounds per square inch on the respective curve in the same section, and reads 33.4 feet of water.

#10. The total head in feet of water is located on the diagram by adding the distance between gauges, 1.5 foot, to the sum of the two ordinates C, and D, being a total of 44.5 feet of water.

#11. Pump horse power. Follow the ordinate of the total head to the intersection with the horse power curve corresponding to the total quantity, and read the abscissa 3.74 H. P.

#12. Power consumed from line is given

by the intersection of the ammeter and voltmeter readings (Section E), showing 5940 watts.

#13. Horse power developed by motor is given by the abscissa corresponding to the watts ordinate on the 650 R.PM. motor curve. It reads 6.42 horse power.

#14. Percent left after slip is given in section E by the ordinate from the pump shaft speed (1250) to the converging line from the reduced motor speed (650x2). It reads 96%

#15. Net motive horse power. Follow the 96% ordinate in section C to its intersection with the line converging from the developed horse power, and read the abscissa 6.16 horse power.

#16. Efficiency per cent is given directly by the percentage ordinate from the pump h horse power (3.74) to the converging line of the net motive power. It reads 60.7%.

#17. Peripheral velocity velocity of impeller is given by the ordinate of its curve (sections D and E) corresponding to the pump shaft speed. It reads 60.8 feet per second.

#18. Head equivalent to peripheral velocity is given by the ordinate of its curve (Section D and E) opposite the respective velocity, and reads 57.9 feet.

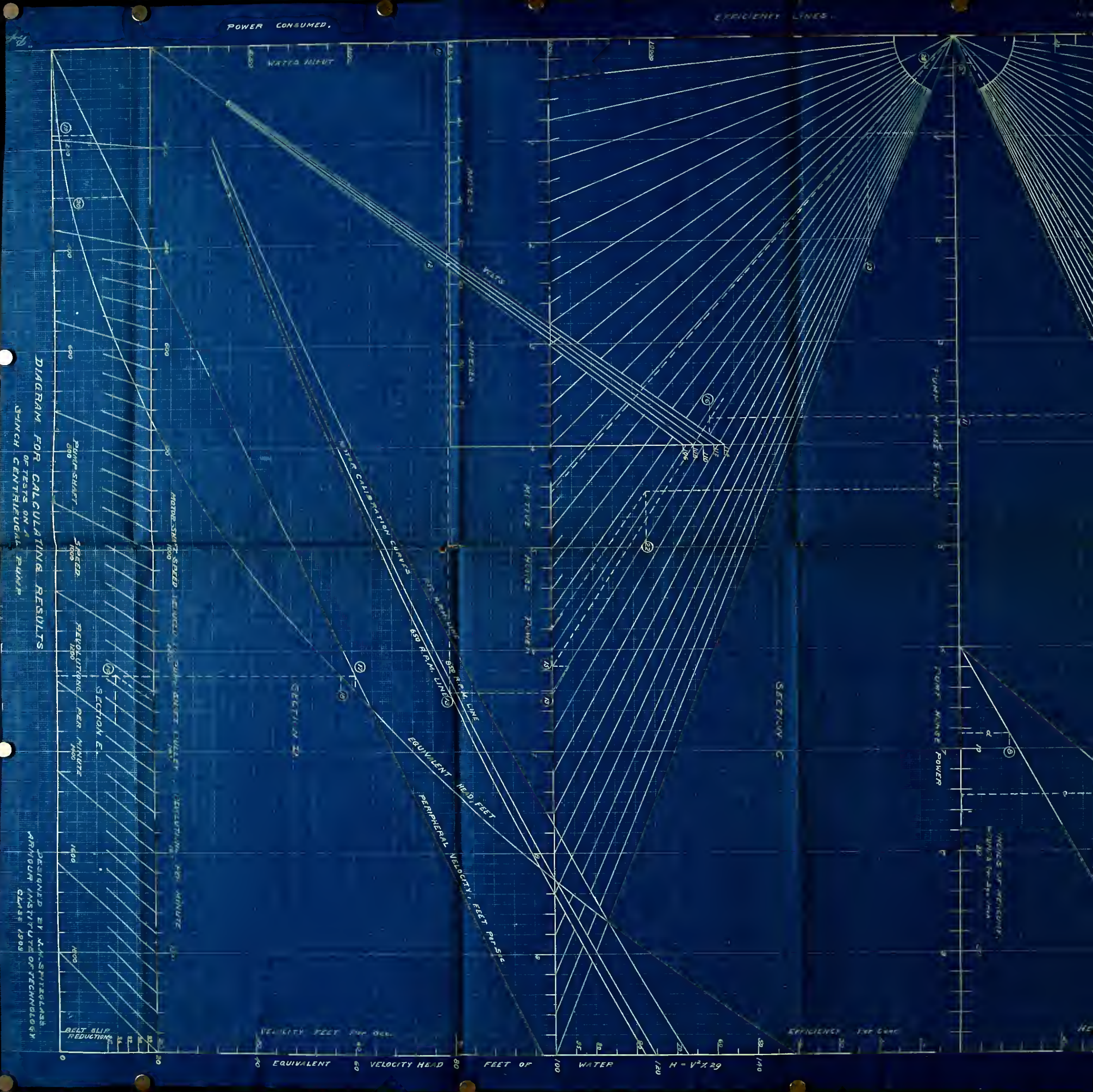
#19, and #20. Inlet and discharge velocity heads are given by the ordinates of the equivalent head curve at the respective velocity curve, reading 1.1, and 3.2 feet respectively.

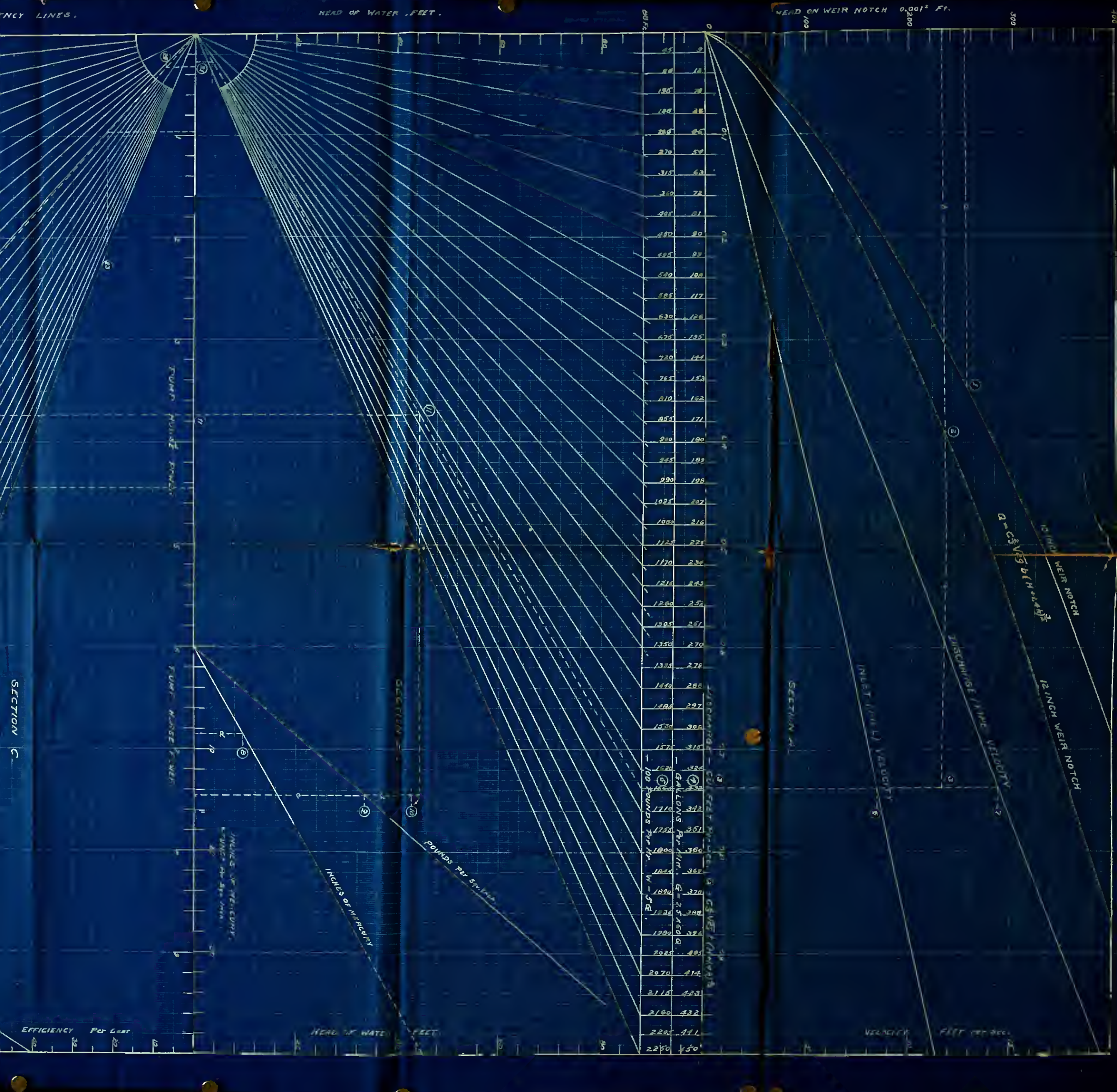
#21. Power rejected in discharge velocity is given by the intersection of the horse power curve from the total quantity with the discharge velocity equivalent head, and reads 0.28 horse power.

#22. Ratio of total head to peripheral velocity head is given by the percentage ordinate (section C) from 4.45 to the line converging from 5.79, the decimal point being shifted in both one place. It reads 76.7%.

#23. Ratio of suction head to total head is given in the same way by the percentage ordinate of 0.96 to the line converging from 4.45 reading 21.5%.

#24. Ratio of rejected head to total head is given by the percentage ordinate of 0.32 to the line converging from 4.45, reading 7.2%.


POWER CONSUMED.
EFFICIENCY LINES.
WATER HEIGHT
VOLTS
PUMP SHAFT SPEED 800
SPEED 1000
REVOLUTIONS PER MINUTE 1200
1400
1600
1800
MOTOR SHAFT SPEED 1000
SECTION E.
SECTION D.
SECTION C.
BELT SLIP REDUCTIONS
CALIBRATION CURVES
650 R.P.M. LINE
850 R.P.M. LINE
EQUIVALENT HEAD, FEET
PERIPHERAL VELOCITY, FEET PER SEC.
MOTIVE POWER
PUMP HORSE POWER
VELOCITY FEET PER SEC.
EFFICIENCY PER CENT
0
20
40 EQUIVALENT
60 VELOCITY HEAD
80 FEET OF
100 WATER
120 H = V² ÷ 2g
140
DIAGRAM FOR CALCULATING RESULTS
OF TESTS ON A
3-INCH CENTRIFUGAL PUMP
DESIGNED BY J.M. SPITZGLASS
ARMOUR INSTITUTE OF TECHNOLOGY
CLASS 1909



…NCY LINES.
HEAD OF WATER, FEET.
HEAD ON WEIR NOTCH 0.001² Ft.
100
200
300
400
PUMP H.P.
PUMP HORSE POWER
SECTION C.
SECTION
SECTION A.
INCHES OF MERCURY
POUNDS Per Sq. Inch
INCHES OF MERCURY
100 POUNDS Per Hr. W = 5G
GALLONS Per Min. G = 7.5 × 60 Q
DISCHARGE - CU. FEET Per SEC. Q = C⅔√2g b(H+1.4h)^{3/2}
45
90
135
180
225
270
315
360
405
450
495
540
585
630
675
720
765
810
855
900
945
990
1035
1080
1125
1170
1215
1260
1305
1350
1395
1440
1485
1530
1575
1620
1665
1710
1755
1800
1845
1890
1935
1980
2025
2070
2115
2160
2205
2250
9
18
27
36
45
54
63
72
81
90
99
108
117
126
135
144
153
162
171
180
189
198
207
216
225
234
243
252
261
270
279
288
297
306
315
324
333
342
351
360
369
378
387
396
405
414
423
432
441
450
Q = C⅔√2g b(H+1.4h)^{3/2}
12 INCH WEIR NOTCH
12 INCH WEIR NOTCH
INLET (SUCTION) VELOCITY
DISCHARGE PIPE VELOCITY
R
P
EFFICIENCY Per Cent
40
30
20
10
HEAD OF WATER, FEET
VELOCITY FEET PER SEC.